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THE TIN-MINING INDUSTRY OF CORNWALL.
By the English Correspondent of SCIENTIFIC AMERICAN.

The county of Cornwall is practically one huge mass of tin lode rock. The veins as a general rule run in a direction from north to south, and for the most part the granite is richly impregnated with the metal. Despite the rich nature of the veins, however, the industry has been severely crippled, unfortunately, by the existence of obsolete feudal laws, whereby heavy royalties and dues have to be paid to the land-owners upon both the percentage of metal raised and also for the rights to work the properties. Some idea of the exacting and heavy nature of these dues may be gathered from the fact that in the course of eighty-three years the Dolcoath mine, which is one of the oldest and richest properties in the county, expended \$1,295,000 in this way, which was more than 25 per cent of the aggregate dividends paid to the shareholders during the same period. Moreover, the system of carrying out the extraction of the mineral is hopelessly antiquated, the same methods which prevailed before the discovery of tin deposits in other parts of the world for the most part still obtaining. During recent years many of the largest and most important mines have been overhauled as regards the working machinery, and although

there is still room for considerable improvement in this connection, yet the state of affairs is much better than existed in the last decade of the past century.

Tin mining is one of the oldest industries in Great

Britain. Since long before the Christian era the Phoenicians plied a thriving trade between Cornwall and the Mediterranean ports. Despite the fact that the metal has been exploited for over a score of centuries, there yet remain several million tons awaiting development. During the year 1905 fifteen mines produced 5,480 tons out of some 100,000 tons, which was the world's production for that year. Of this aggregate some 1,697 tons were procured from the Dolcoath mine alone, which is the largest and most famous in the county, the value of the output representing £734,910.

In the course of a century approximately six million tons of black tin have been obtained from this mine. On all sides of the pit mouth over a considerable acreage may be seen huge desolate mounds of dead slate-colored rubble—the accumulation of centuries. The mine itself is the deepest in the county, the lowest working level being 3,600 feet, while the underground galleries extending in all directions and at varying levels aggregate over 80 miles in length. The mine is entered by the ancient mouth, the descent being by means of a cage. At the points where the veins of tin lode occur at different levels, cross drives branch off on all sides from the main shaft. The cross tunnels are for the most part driven north and south, which is the direction



THE LADDERS BY WHICH THE MINERS REACH THE VARIOUS LEVELS. THIS PICTURE WAS TAKEN AT THE 1,116 FOOT LEVEL OF THE EAST POOL MINE, CORNWALL.



TRAMMING TIN STUFF AT THE 2,472 FOOT LEVEL OF THE DOLCOATH MINE, CORNWALL.



MAN ENGINE IN THE DEPTHS OF THE DOLCOATH TIN MINE, CORNWALL.



"GIG" AT THE 1,959 FOOT LEVEL OF THE DOLCOATH TIN MINE.

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generally followed by the tin-bearing veins. The shaft of a tin mine is invariably divided into two sections by a wooden partition, one serving as the passage through which the ores are brought to the surface, while the other acts as the entrance and exit for the miners. The latter before descent take a tallow candle, and by means of a lump of moist clay convert their hats into candlesticks. This is the only illuminating device with which he is equipped, and by reason of its primitive nature the light produced is both flickering and dim.

In the lower levels the heat is almost suffocating in its oppressiveness, and the miner must necessarily be of splendid physique to withstand the rigors and labor of toiling in such temperatures, the heat rising in the proportion of one degree F. for every descending 53.5 feet. So intense is the heat in the lower levels, that the miners for the most part can work only half-clad, and then only for half-hour stretches, their comrades meanwhile dashing cold water over them. At places the working faces are in large, spacious caverns, while in others the gallery is so narrow and low that the man has to toil in a cramped and difficult position. Where the strata of tin and copper lodes are richest, the rock with which they are impregnated is exceedingly hard, so that drilling becomes a tedious and laborious operation. In such places the chisel and hammer, which constitute the miner's principal equipment, make but little impression, and blasting has to be resorted to. A sum of about \$90,000 is expended annually in explosives alone. The hole is bored with a rock drill, and a cordite cartridge with a safety time fuse inserted and tampered home. At the critical moment the miner shouts "Fire," at which signal all his companions in the vicinity, together with himself, retire to a safe distance. "Firing the hole," as it is called, disintegrates the rock. The shattered pieces are then loaded into little trolleys or skips, and hauled by ponies or pushed by the men themselves from gallery to gallery until the main shaft is reached. They are then hoisted to the surface. The tin miner is essentially a skillful worker. Often the cross cuts are driven by the simple guidance of the compass, and a shaft is frequently commenced at different depths, requiring cutting with such exactitude, that when completed, the sections coincide and form a continuous vertical excavation.

Although the tin miner is spared the terrors of fire damp, which constantly confront the coal miner, yet he has a more terrible enemy in water. In the lower levels the men are engaged almost waist deep in water and slime heavily impregnated with arsenic, to the presence of which poison miners' phthisis is largely attributable, from which malady about seventy per cent of the Cornish miners ultimately succumb. An adit is usually driven up to the vein from a convenient valley, so that the level to which the water is to be pumped may be brought as low as possible. The pumping plant has to be kept in operation night and day without cessation, and the quantity of water discharged from a single mine occasionally amounts to as much as 1,600 gallons per minute, and as much as 37,000,000 tons of water have been discharged from sixty mines in the course of a year.

The miners work in eight-hour shifts, which spell includes intervals for meals, so that the actual working period is about six hours. That such a shift is sufficiently lengthy is plainly recognizable from the condition of the men, especially those working in the lowest levels, upon their emergence from the shafts. At the greatest depths, owing to the sultry atmosphere prevailing, the less stalwart miners often lose as much as five or six pounds in weight in perspiration during a single spell. From this it will be realized

that an unusually good physique on the part of the men is required, in order to withstand the severe strain that is imposed upon the system.

Unfortunately, the depression in the tin industry has been attended by a corresponding depreciation in the available labor. The more expert miners have emigrated to the various colonies and American mines as the Cornish tin miners languished and ultimately

flour. This process liberates the particles of tin from the quartz, but the metal is so heavily associated with other minerals, such as copper, sulphur, and iron, that it has to be subjected to a prolonged series of washings in order to extract the pure tin. The powdered quartz is passed over a number of washing tables by means of a steady stream of water. As the tin is the heaviest substance it quickly gravitates to the



CHISEL WORKING ON THE 450 FOOT LEVEL OF THE EAST POOL MINE, CORNWALL.

closed down. The extent of this depression may be gathered from the fact that whereas fifty years ago there were 50,000 men engaged in the mines, in the year 1904 this aggregate had dwindled to 6,225, of which total only 3,500 men were underground workers. It is the scarcity of expert labor which is now handicapping the revival of the industry, and this problem promises to become more acute in the immediate future. Attempts to remedy the deficiency are being made by educating students as far as possible for the work, but such methods are not comparable with the hereditary experience which formerly prevailed, the mining skill being then handed down from father to son through successive generations. Mining labor, so far as the underground work is concerned, is divided broadly into three classes, viz.: (1) "tut work," or contract labor; (2) "tribute," or payment by results; and (3) ordinary wage paid labor. To the experienced miner the former two classes are preferable, despite the element of speculation which enters into the schemes, since they call for skill, good judgment, and energy upon his part. The ground may open out and the lode work more easily than anticipated; on the other hand, the reverse conditions might be encountered, the vein working hard and poor in yield, in which event the miner is distinctly the loser, but the system has the salient advantage that it produces a valuable class of laborers.

The ore upon its arrival at the pit's mouth is pulverized into small lumps either by the manual labor of girls or machinery preparatory for the steam or water driven stamps. The rock is here submitted to heavy pounding beneath ponderous rams or stamps, and crushed into fine powder of the consistency of

bottom of the pans, and collects in a sediment of black mud, which is subsequently dug out and packed into tubs, the product being known as "black tin" and sold under what is termed "wet weight." The cost of excavating, raising, and treating the ore approximates about six dollars per ton, the average yield from a ton of ore being about 51.25 pounds—about 2.3 per cent. One ton of black tin yields about 70 per cent of white metal.

The tailings are treated on similar lines until almost the whole of the metal is recovered. Between the mines and the sea is a stream known as the "six miles." At frequent points throughout its course men known as "streamers" have installed bubbles, frames, dipper wheels, pulverizers, and settling pits, for the recovery of that metal which has escaped the "vanning" process, as the sluicing over the moving tables is called. In this case the water tumbling over the rocky bed causes the tin to be released from the waste, and it is thus recovered. The output of the "streamers" alone is now worth approximately \$300,000 per annum, and these men also find it profitable to work the old mine heaps, i. e., the huge masses of excavated ballast dumped around the mouths of the shafts. In former times, owing to the primitive methods adopted for recovering the tin from the ore, a large quantity of metal was unavoidably left behind. Now these waste heaps are being leveled and the contents pulverized, stamped, and washed, and a fair yield is obtained. It is in this phase of the operations that some process similar to the cyanide method for dissolving gold in the tailings of gold mines is required for obtaining the tin from the tailings, since it is impossible to extract all the tin from the crushed ore by existent practices.

Accompanying the present revival in the industry, however, there has been a decided movement in reorganizing the machinery equipments of the mines, and a large amount of capital is being expended in this direction. By this means great economies in working are being effected, which with the older types of machinery were impracticable, while the yield per ton of ore is being rendered considerably higher. The magnetic separator is gradually coming into vogue, since there are many mines where the ores are very poor, and which are otherwise scarcely profitable in working, that can be rendered more remunerative by the utilization of this process, the ores being peculiarly adapted for such treatment. The commercial possibilities of this system were first demonstrated in the magnetic separation of tin from wolfram at the San Flins mines in Spain, and its application in Cornwall though so far limited in extent has been equally successful.

The employment of this scientific process has also resulted in another distinct advantage. The tin ore as already mentioned is largely impregnated with other valuable minerals, such as copper, zinc blende, galena, tungsten, and arsenical and iron pyrites. Formerly only the tin (more essentially) and the copper were sought, the other minerals being ignored. The reason for this procedure, however, was that owing to their occurrence in a complex form they did not pay to work, and the smelter when offered these concentrates only paid for one of the contents, tin or copper as required, and regarded the presence of the other substances merely as impurities. Consequently, the concentrated ores were often sacrificed for less than they cost to raise. The extent of this ignorance is strikingly shown in the case of the Wheal Trenwith mine at St. Ives, which is to be reopened. The refuse dumps around the mouth of the shaft are largely composed of uranium in the form of pitch blende.



DRILLING AND BLASTING HALF A MILE BELOW THE SURFACE IN THE TINCROFT MINE, CORNWALL.
SUCH IS THE HEAT THAT THE MEN MUST WORK STRIPPED TO THE WAIST.

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When the mine was worked in former days for its copper, this pitch blonde was considered a nuisance. The miners at first carefully collected it and placed it on one side, under the impression that it was black copper ore. But when smelted the percentage of copper was found to be so small and inferior in quality that the miners and owners were disgusted. A sample was submitted to an analyst, who, ignorant in

739,697,000 and the total value of their exports is set down at \$12,496,419,000, these figures of exports including only the domestic products exported and not including the foreign or colonial merchandise brought into the country and re-exported. The total imports of the countries other than the United States are given at \$12,513,143,000 and the share of these imports drawn from the United States at \$1,798,338,000, or

ico, 68.60 per cent; Santo Domingo, 65.16 per cent; Colombia, 54.01 per cent; Nicaragua, 53.21 per cent; Costa Rica, 47.14 per cent; the Philippines, 36.28 per cent; Venezuela, 31.11 per cent; Canada, 30.41 per cent; Guatemala, 34.9 per cent; Japan, 29.48 per cent; Ecuador, 27.32 per cent; Salvador, 21.72 per cent; Chile, 15.2 per cent; Switzerland, 12.90 per cent; Italy, 11.95 per cent; China, 11.86 per cent; Germany, 9.46 per cent; Peru, 9.34 per cent; Haiti, 8.84 per cent, and the United Kingdom, 7.25 per cent of the total exports.

The countries in which the largest share of the trade occurs with the United States are as a rule those of the American continent and those lying nearer to its markets than to those of other countries, while in a large proportion of cases their products are of the character especially required in the United States and their requirements chiefly of the character of articles largely produced in the United States. Mexico, separated from the United States only by an imaginary line, and penetrated by railroad lines which are operated in close conjunction with those of the United States, takes practically 66 per cent of its imports from this country, and sends 68.6 per cent of its exports to our markets. Manufactures, breadstuffs, meats, and coal are the principal articles forming this large share which Mexico takes from the United States, and sisal, copper in ore and pigs, lead, hides and skins, and coffee and other tropical products are the principal articles forming the large share of her exports sent to us.

Canada, also separated from the United States only by an imaginary line and with close railroad and other facilities for intercommunication, takes practically 60 per cent of her imports from the United States and sends 30 per cent of her exports to this country, the imports being largely manufactures (especially of iron and steel), coal, breadstuffs (especially corn), cotton and cotton manufactures, boots and shoes and other manufactures of leather, and mineral oils. Her chief exports to the United States are copper, in ore and pigs, nickel ore, hides and skins, timber and lumber, wood pulp, fish, and furs.

The Central American States draw practically one-half of their imports from the United States and send to us a like proportion of their exports, the bulk of the imports from the United States being manufactures and foodstuffs, and the bulk of their exports to the United States tropical products, specially fruits, coffee, and woods.

The countries of the northern part of South America, those fronting upon the Caribbean, also take a large share (averaging about one-third) of their imports from the United States, and send an equally large share of their exports to the United States, and the character of these imports from and exports to this country is similar to that already mentioned for the Central American States.

Cuba sends 86½ per cent of its exports to the United States and takes 45 1-3 per cent of its imports from this country, the exports in question being chiefly sugar and tobacco, and the imports railway supplies, lumber, manufactures of all sorts, foodstuffs, and coal.

Brazil, which supplies a very large share of our coffee and rubber, sends us 41 per cent of its exports and takes 10 1-3 per cent of its imports from us, the latter composed chiefly of manufactures and meats.

In the case of European countries, the percentage which American products form of the imports is much larger than that which products for the United States form of the exports. In the case of the United Kingdom, for example, the imports from the United States formed 20.45 per cent of the total, while of the exports, the share sent to the United States was 7.25 per cent. In the case of Germany imports from the United States formed 13.91 per cent of the total, and exports



BREAKING AND LOADING EXCAVATED ORE AT 2,472 FOOT LEVEL, DOLCOATH MINE, CORNWALL.

those days of the value of pitch blonde, seriously informed the miners of its nature and prejudices, with the result that it was discarded as rubble. These refuse heaps have since been carefully investigated, and it has been discovered that the pitch blonde is of excellent quality and exceptionally abundant. These discoveries have since resulted in the extraction of other minerals present in the discarded ore in addition to the desired tin, and although the quantities obtained are small, yet by the exercise of due economy in treatment their extraction can be rendered sufficiently profitable.

The means adopted for the disposal of the black tin by the miners is decidedly curious. The miners, who have defrayed the whole expense of raising and dressing the tin, receive as their reward a percentage upon the amount realized at auction. These sales take place weekly, and each miner displays the quantity of his product in heaps up to one hundred tons in bulk. Each purchasing agent examines the samples, and indicates upon a piece of paper the price he is prepared to offer per ton. These slips of paper are handed to the auctioneer, who then selects the highest bidder, who thus becomes the purchaser. In this manner several thousand tons of black tin are disposed of without a single word being uttered. The percentage yield to the miner as a result of his work varies from 3 to 60 per cent on the dollar, according to the richness or poverty of the ore obtained. The principle of working "payment by results" saves the owner a considerable amount of detailed survey in mining, while at the same time it stimulates the miner to raise as much ore as possible. Should the miner, however, be so unfortunate as to strike a bad pitch and regret his bargain, he can retract from his undertaking by the payment of five dollars and select a new claim.

While the Dolcoath is the most famous and important of the Cornish tin mines, and furthermore has the deepest workings, the Tincroft and Levant mines are also notable. In the latter case the galleries are driven out in the bed of the Atlantic, the most distant point of the subterranean working from which the ore is extracted being about one mile from the shore in the sea-bed. The ores there obtained are exceptionally good, being rich not only in tin, but in copper and arsenic as well. With this mine, however, the greatest difficulty is encountered in connection with water, the galleries being only a little below the surface of the ocean bed.

INTERNATIONAL COMMERCE OF THE WORLD AND SHARE OF THE UNITED STATES THEREIN.

The international commerce of the world now exceeds 26 billions of dollars, of which 13½ billions is imports and 12½ billions exports. Of the imports of countries other than the United States, 14 1-3 per cent are drawn from this country, and of their exports, 9½ per cent are sent to us.

This is a summarization of a table published in the annual Statistical Abstract of the United States, just issued by the Bureau of Statistics of the Department of Commerce and Labor. It shows the total imports and total exports of each country of the world for which statistics are available in the latest year for which figures can be had, a large proportion of the statements relating to the commerce of the year 1905, though in a few cases they are for the year 1906 and in certain other instances necessarily accept 1904 as the latest date for which statistics can be had.

The total value of the imports of all the countries for which statistics are available is set down at \$13,

14.37 per cent of the total. The total exports of the countries other than the United States are given at \$10,778,466,000 and the share sent to the United States at \$1,031,113,000, or 9.57 per cent of the total.

The share which the United States supplies of the imports of the various countries of the world and which it takes of their exports is shown by an examination of the details, and this examination discloses some interesting facts. The country which draws the largest share of its imports from the United States is Honduras, which in 1905 took 73.7 per cent of its imports from this country. Next in rank in this particular is Santo Domingo, of whose imports in 1905 71.65 per cent were from the United States. Mexico in the same year took 65.99 per cent of its imports from the United States; Canada, 59.59 per cent; Nicaragua, 52.09 per cent; Costa Rica, 51.65 per cent; Cuba, 45.34 per cent; Guatemala, 39.55 per cent; Haiti, 35.56 per cent; Colombia, 34.15 per cent; Salvador, 31.18 per cent; Venezuela, 30.22 per cent; Ecuador, 28.86 per cent; Japan, 21.35 per cent; United Kingdom, 20.45 per cent; Peru, 17.98 per cent; the Philippines, 16.8 per cent; China, 16.68 per cent; Denmark, 16.08 per cent; Argentina, 14.1 per cent; Germany, 13.91 per cent; Italy, 12.48 per cent; the Commonwealth of Australia, 11.7 per cent; New Zealand, 11.21 per cent; Spain, 11.21 per cent; France, 10.72 per cent; Brazil, 10.33 per cent; Chile, 9.92 per cent; Uruguay, 9.67 per cent; Russia, 9.66 per cent; Austria-Hungary, 9.49 per cent; Netherlands, 9.38 per cent; Bolivia, 8.45 per cent; Belgium, 7.98 per cent; Sweden, 7.22 per cent; Portugal, 7.13 per cent, and Korea, 6.19 per cent.

Considering the share of the exports of the various countries sent to the United States in the order of the relative share, the table shows that Cuba sends to the United States 86.53 per cent of its total exports; Mex-



DUMPING ORE TO BE RAISED TO THE SURFACE AT THE 2,056 FOOT LEVEL OF THE COOKS KITCHEN MINE, NOW THE TINCROFT MINE, CORNWALL.

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to the United States 9.46 per cent of the total. In the case of Italy, imports from the United States formed 12.48 per cent of the total, and exports to the United States formed 11.95 per cent of the total. In the case of Austria-Hungary, merchandise from the United States formed 9.49 per cent of the total imports, and that sent to the United States formed 2.36 per cent of the total exports. In the case of France, merchandise from the United States formed 10.7 per cent of the total imports, and that sent to the United States, 6 per cent of the total exports.

In the Orient conditions vary greatly, according to the peculiar circumstances. In the case of Japan, merchandise from the United States formed 21.35 per cent of the imports, and consignments to the United States 29.48 per cent of the exports. In the case of China, merchandise from the United States formed 16.68 per cent of the imports and that sent to the United States 11.86 per cent of the exports. In the case of India, merchandise from the United States formed but 1.47 per cent of the imports, while that sent to the United States formed 6.13 per cent of the exports. In the case of Java, merchandise from the United States formed 1.66 per cent of the imports and that sent to the United States formed 8.25 per cent of the exports. In the case of Turkey, imports from the United States formed but one-fourth of 1 per cent of the total, and merchandise sent to the United States formed 2.76 per cent of the exports.

[Concluded from SUPPLEMENT NO. 1634, page 26179.]

THE USE OF ALCOHOL AND GASOLINE IN FARM ENGINES.*

By Prof. C. E. LUKE and S. M. WOODWARD.

ELEMENTARY ENGINE MECHANISM.

EVERY exploding engine operating with crude oil or its distillates, or alcohol, must have certain parts, no matter how different engines may vary in other details. These parts are a cylinder in which a sliding plug or

the volume displaced by the piston, and this fresh mixture will be mixed with some burnt gases. At the end of suction the inlet valve is closed and compression begins (Fig. 2), continuing through the second stroke. During this process both valves are closed and the fresh charge, together with the residue of burnt gases, is squeezed into the clearance space so that it will have as a result a considerable pressure, called the compression pressure, preparatory to exploding. At the end of compression an electric spark explodes the charge, causing the pressure to rise two to four and one-half times the compression pressure. This high pressure in the clearance space will then drive the piston forward. This stroke, the third or outstroke (Fig. 3), is accomplished by the high pressure of the gases filling the explosion chamber and during the progress of the piston the pressure gradually falls, as expansion takes place. During this time both valves are closed, as during the compression. At the end of the expansion (Fig. 4) the exhaust valve opens and the piston returns under the influence of the flywheel, which has been spun around by the explosion, giving the fourth stroke or instroke. The exhaust valve being open for this stroke, most of the burnt gases are expelled, but some are retained in the clearance. After this the fifth stroke begins, which is the same as the first stroke, and subsequently the whole series repeats itself indefinitely and automatically.

While the above operations are usual and the above parts are likewise important, an engine having no more mechanism than is shown would not run. There will be required in addition to what is shown a valve gear, which is a mechanism for opening and closing the valves at the proper time. There must be also some device for making a mixture having the proper characteristics for explosion. This mixture will consist of air and the vapor of the liquid fuel, so that there must be supplied a carburetor, which vaporizes and mixes at the same time, or a vaporizer which vaporizes without mixing. There must also be a mech-

amount of oxygen, or mixed with any solid or liquid containing oxygen in the right amount, then explosive combustion is possible. If such a mixture be ignited at one point by heating it by a flame, a hot plate, or an electric spark, the combustion will travel through the entire mass of its own accord. Otherwise stated, the combustion will be self-propagating. When a mixture has this property of self-propagation of combustion it may be said to be explosive, whether the propagation be fast or slow or whether the explosion be accompanied by noise or not. Gunpowder consists of fuel in the form of carbon or charcoal, together with a little sulphur and a salt, such as a nitrate, containing oxygen. A long train of powder will completely inflame itself if lighted at one point. If the powder be of good quality and pure, the flame will propagate very rapidly. If, however, the powder has some sand or dirt mixed with it, the flame may still propagate, but more slowly, and finally, if there is too much dirt or inactive material present, it will be impossible to ignite the whole mass by self-propagation. Engine mixtures do not consist of solid fuel like gunpowder with oxygen in the nitrate form, but on the contrary consist always of gaseous fuel or liquid fuel vapor mixed with air. The combustion of gaseous mixtures is very much the same in nature as the combustion of gunpowder, which is not thought of as a mixture but which really is. If a mass of explosive mixture be contained in a vessel or in a glass tube and be ignited at one end of the tube, the eye can distinctly follow a flame traveling through the tube. The entire tube does not show a flame at any one time, but instead it will be found that the flame is in the form of a disk or cap and that this flame cap travels through the tube, the flame cap being blue in color, with slight variations. When it has traveled past a certain point all the mixture between that point and the place where the combustion started is burnt, and all the mixture beyond the flame cap is still unburned.

Limits of Proportion.—When the air and vapor are

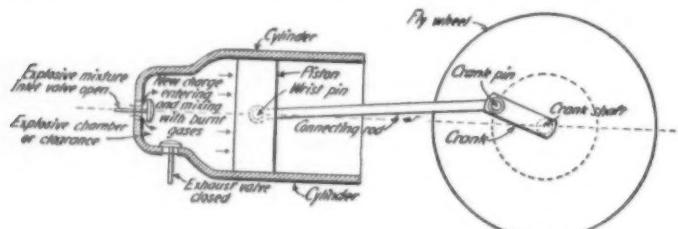


FIG. 1.—DIAGRAM SHOWING MECHANISM OF INTERNAL COMBUSTION ENGINE—SUCTION STROKE.

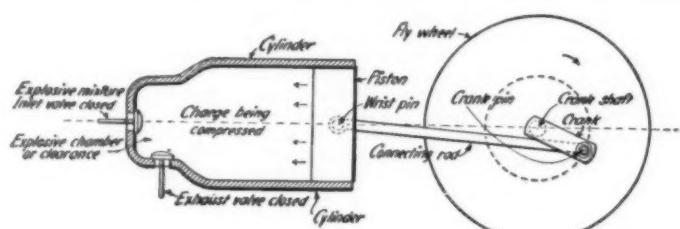


FIG. 2.—DIAGRAM SHOWING MECHANISM OF INTERNAL COMBUSTION ENGINE—COMPRESSION STROKE.

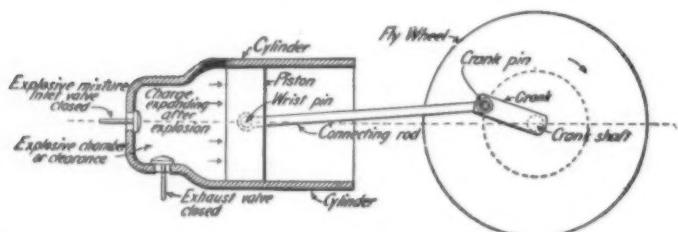


FIG. 3.—DIAGRAM SHOWING MECHANISM OF INTERNAL COMBUSTION ENGINE—EXPANSION STROKE.

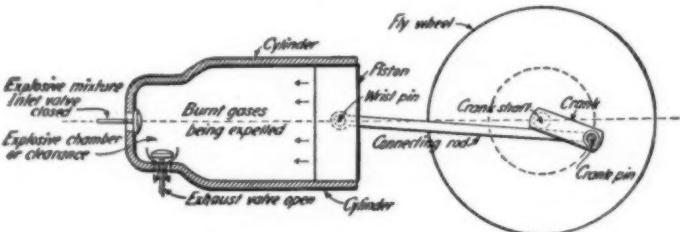


FIG. 4.—DIAGRAM SHOWING MECHANISM OF INTERNAL COMBUSTION ENGINE—EXHAUST STROKE.

piston works back and forth, carrying a pin called the wrist pin, to which is fastened a connecting rod, the other end of which fits in another pin called a crank pin. This crank pin is at one end of an arm called the crank, on the other end of which is the shaft or crank shaft. The piston moves back and forth in the cylinder, but when nearest the cylinder head there is still some space left between the walls, valves, and the piston head. This space is called the clearance, or the explosion chamber, and is the space in which the charge is compressed before it is exploded. In the clearance walls or cylinder head there are two valves in the form of disks, which cover the openings or ports. Through one of the valves an explosive mixture, having certain characteristics to be explained later, is admitted from the source of fuel supply and from the air. Through the other valve the products of combustion after an explosion are expelled. Their duty gives these valves the names of inlet and exhaust valves, respectively. Four strokes are usually required to complete the cycle of events occurring within the cylinder, and to engines requiring these four strokes the name four-stroke cycle or four cycle is given. There are certain other engines with different valve arrangements, which may complete a series of operations in two strokes and these are called two-cycle engines.

The series of operations requiring four strokes is best illustrated by a set of diagrams. In Figs. 1 to 4 is shown a cylinder with the parts connected to it. On the first stroke or outstroke (Fig. 1) the piston is drawn forward either by hand when starting or by the action of flywheels after the engine is put in motion. This moving forward of the piston is accompanied by an opening of the inlet valve, permitting the explosive mixture to follow the piston and fill the cylinder. The clearance space, before this suction stroke begins, is filled with burnt gases from the previous explosion, so that the amount of mixture drawn in will be equal to

the amount of oxygen in the cylinder. This mixture will be mixed with some burnt gases. At the end of suction the inlet valve is closed and compression begins (Fig. 2), continuing through the second stroke. During this process both valves are closed and the fresh charge, together with the residue of burnt gases, is squeezed into the clearance space so that it will have as a result a considerable pressure, called the compression pressure, preparatory to exploding. At the end of compression an electric spark explodes the charge, causing the pressure to rise two to four and one-half times the compression pressure. This high pressure in the clearance space will then drive the piston forward. This stroke, the third or outstroke (Fig. 3), is accomplished by the high pressure of the gases filling the explosion chamber and during the progress of the piston the pressure gradually falls, as expansion takes place. During this time both valves are closed, as during the compression. At the end of the expansion (Fig. 4) the exhaust valve opens and the piston returns under the influence of the flywheel, which has been spun around by the explosion, giving the fourth stroke or instroke. The exhaust valve being open for this stroke, most of the burnt gases are expelled, but some are retained in the clearance. After this the fifth stroke begins, which is the same as the first stroke, and subsequently the whole series repeats itself indefinitely and automatically.

Different makes of engines differ in the above details. All have some provision for performing what is pointed out as necessary, and it is here that inventors and engineers exhibit their skill. All of these engines work as a result of the combustion of the explosive mixture of vapor and air, and a proper understanding of how the various styles of mechanism or changes in detail may affect the engine, requires a preliminary knowledge of their effect upon the explosive mixture.

EXPLOSIVE MIXTURES.

It is easy to understand how an engine may operate without understanding the well-known facts concerning explosive mixtures; but it is impossible to comprehend why engines should differ in fuel consumption or horse-power, good regulation, or any other characteristic without first studying in detail the influence of the mechanism on the composition of the explosive mixture.

Any fuel will burn when there is oxygen present in proper quantity and when the fuel has previously been heated sufficiently. This is true for any kind of combustion, such as the burning of wood, coal, oil in a lamp or cook stove, or gas issuing from an illuminating jet, as well as mixtures in exploding engines. When a fuel is mixed with air containing the right

amount of oxygen, or mixed with any solid or liquid containing oxygen in the right amount, then explosive combustion is possible. If such a mixture be ignited at one point by heating it by a flame, a hot plate, or an electric spark, the combustion will travel through the entire mass of its own accord. Otherwise stated, the combustion will be self-propagating. When a mixture has this property of self-propagation of combustion it may be said to be explosive, whether the propagation be fast or slow or whether the explosion be accompanied by noise or not. Gunpowder consists of fuel in the form of carbon or charcoal, together with a little sulphur and a salt, such as a nitrate, containing oxygen. A long train of powder will completely inflame itself if lighted at one point. If the powder be of good quality and pure, the flame will propagate very rapidly. If, however, the powder has some sand or dirt mixed with it, the flame may still propagate, but more slowly, and finally, if there is too much dirt or inactive material present, it will be impossible to ignite the whole mass by self-propagation. Engine mixtures do not consist of solid fuel like gunpowder with oxygen in the nitrate form, but on the contrary consist always of gaseous fuel or liquid fuel vapor mixed with air. The combustion of gaseous mixtures is very much the same in nature as the combustion of gunpowder, which is not thought of as a mixture but which really is. If a mass of explosive mixture be contained in a vessel or in a glass tube and be ignited at one end of the tube, the eye can distinctly follow a flame traveling through the tube. The entire tube does not show a flame at any one time, but instead it will be found that the flame is in the form of a disk or cap and that this flame cap travels through the tube, the flame cap being blue in color, with slight variations. When it has traveled past a certain point all the mixture between that point and the place where the combustion started is burnt, and all the mixture beyond the flame cap is still unburned.

Temperature of Ignition.—By careful experimenting in scientific laboratories it has been found that explosive mixtures of different fuels do not all ignite at the same temperature; that some, for instance, must be heated to a higher temperature than others to start combustion. It has been found also that the temperature of ignition is lower for any given fuel when there is just a little excess of fuel in the mixture. If the mixture contains much excess of fuel, it must be heated to a higher temperature before ignition can be started. The temperature of ignition for any mixture will not be raised by adding inactive gas or by chang-

* Reported from Farmers' Bulletin 277, issued by the United States Department of Agriculture.

ing properties, but it may take a longer time to ignite when weak.

It has been found that raising the pressure or raising the temperature of the mass before attempting to ignite it will cause it to apparently ignite more easily. The time necessary to start ignition is lessened if the mixture is confined so that it cannot circulate. It appears that a mass of mixture being heated at one point in an attempt to ignite it acts very much like the air in a room when the room contains a radiator for heating. The mixture near the radiator rises before becoming very hot, and it takes some time before any part of the mixture can be raised to the temperature sufficient to ignite it unless the circulation is suppressed. While no exact figures are available for the temperature of ignition for the mixtures used in these exploding liquid fuel engines, they can be placed in the following order:

Kerosene mixtures have the lowest temperature of ignition.

Gasoline comes next, but is quite close to kerosene.

Alcohol mixtures have the highest temperature of ignition and are quite far removed from kerosene and gasoline.

Rate of Propagation.—The velocity with which the flame cap travels through the mass of mixture is termed the "rate of propagation," and this is sometimes very high and sometimes very low. Mixtures containing a certain small excess of fuel over what seems to be chemically correct burn faster than any other mixtures of that fuel. With much excess of fuel, much excess of air, or much neutral gas, the rate of propagation becomes lower, so that mixtures burn slower the further they depart from the proper chemical proportions (with the exception noted) or the more inactive or neutral gas they contain. The nature of the fuel has an influence on the rate of propagation and for our purpose it is only necessary to cite kerosene, gasoline, and alcohol mixtures. Kerosene mixtures burn fastest, and so have the higher rate of propagation. Next come gasoline mixtures and lastly alcohol, with the lowest rate of propagation, assuming, of course, always the correct mixtures in each case. The higher the pressure of the mixture before ignition the faster it will burn, so that the rate of propagation depends upon the pressure. Similarly, the hotter the mixture when ignited the faster it will burn, so that increase of temperature makes it burn faster or raises the rate of propagation. The shape of the chamber containing the mixture has a very decided effect on the rate of propagation. It was found by observing mixtures burning in glass tubes that, when very small tubes were used, the rate of propagation became perceptibly retarded, and when extremely small tubes were used the rate of propagation was zero; that is to say, the tube can be made so small that the flame will not propagate itself through the tube at all. This is because with very small tubes the heat can be conducted away from the flame faster than the flame liberates it, with the effect that combustion ceases simply by cooling, just as water quenches a fire. If, in a tube so small as to prevent propagation, the mixture be compressed, it will liberate heat faster by reason of its greater density, and self-propagation will then be possible. It appears, then, that affecting this rate of propagation there is a whole series of influences, some tending to make it less, others more, with the consequent result of making it difficult to predict what will happen in a new case. A knowledge, however, of these causes of increase and decrease is essential in the interpretation of engine results, because the rate at which pressure rises in the cylinder after explosion depends upon the relation between the rate of propagation in the mixture and the piston speed of the engine. The motion of the piston outward tends to lower the pressure, while combustion by self-propagation tends to raise it. If the piston speed be small in proportion to the rate of propagation the pressure will rise in the cylinder rapidly. If, however, the piston speed be great and the rate of propagation small, the pressure may not rise at all in the cylinder or it may even fall during the explosion.

Apart from the mere question of average velocity of propagation, there is another question of great importance, and that is the mode of propagation. It has been shown by the work of the French scientists that there are three modes of propagation, or that the wave cap travels through the mass in three ways, each producing different effects and all of them influencing the performance of an engine. If the mass be free to expand while burning, the flame will communicate its heat to the next layer of mixtures and so ignite it. Thus by successive heatings of layers the flame would propagate "uniformly." The expansion of the burnt gas, however, if explosion takes place in a chamber confining the mixture, under the influence of the heat generated by the combustion, seems to start a pressure wave through the mass similar to a sound wave, and the flame cap can be seen to oscillate in its advance. This is said to be an "undulatory" movement, which is the second mode of propagation. If by any series of circumstances a number of waves of this kind should be set up in the mixture so that the crests of one wave matched the hollows of another, the waves would be eliminated. If, on the contrary, the crests of the first be superimposed on the crests of the second, third, etc., the waves would be synchronized and produce momentary high pressure, localized at the point representing the wave crest, thus giving rise to the third mode of propagation, the explosive wave. In any case a wave in the mass that may synchronize with waves of combustion will exaggerate the possibility of producing the explosive wave. Agitation of the mass, such as is produced by a jet impinging into the main mass, will do

this, and so will a wave of piston compression. This is a matter of very considerable importance in engines, for, if the exhaust chamber be not of the right form, there may be pockets or isolated masses of mixture so placed that ignition starting in one will raise the pres-

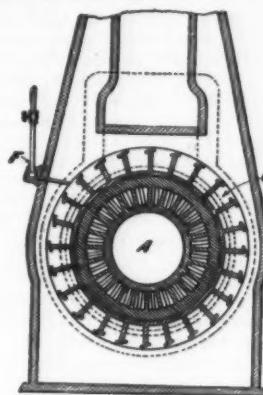


FIG. 5.—SECTION OF RETORT VAPORIZER.

ure in that, causing a flow of gases toward the other with a corresponding agitation and synchronizing of waves, resulting in the explosive wave. An explosive wave gives rise to pressures in this way very much in

they can be divided into two classes: The first, crude petroleum and its distillates, which have some characteristics in common; and the second, alcohol, which is quite different from any of the petroleum distillates in all of its characteristics. When crude oil is boiled or refined, vapors are evolved which may be condensed. These condensed vapors are called "distillates." In a refinery the temperature of the vapor coming off is measured and the distillates collected either between two limits of temperature or two densities, for as the boiling proceeds the temperature of the liquid and vapor continually rises and the density of the distillates also continuously rises. The first distillates are light and the last heavy. The last distillates constitute lubricating oils; the first and intermediate distillates constitute gasoline, naphtha, kerosene, etc., available for revaporation for use in exploding engines. These distillates are not simple fuels, but are mixtures of different chemical composition, always containing carbon and hydrogen. They comprise all the material that goes over in the boiling between two limiting densities, the mixtures having a sort of average density.

There is not a good agreement between the character of the materials designated gasoline, kerosene, etc., and the temperature of distillation and densities employed in different places, so that such names seem to have more commercial significance than scientific value. The following table shows one set of values that is probably as good as any densities reported, they being compared with water and given in Baume's hydrometer scale at 59 deg. F.:

Definition of petroleum distillates.

Name.	Boiling point.	Specific gravity.	Density.
Petroleum ether.	104-158	0.650-0.660	85-89
Gasoline.	158-176	.660-.700	80-88
Naphtha C.	176-212	.670-.707	78-88
Naphtha B.	212-246	.707-.722	68-74
Naphtha A.	246-302	.722-.737	64-69
Kerosene.	302-572	.738-.864	56-82
Lubricating oil.	572 bp	.864-.960	32-15

excess of the pressure due merely to the heat liberated, reaching 600 pounds per square inch in the engine cylinder. If the ignition be early; that is to say, if ignition be started while the piston is still compressing gas, there will invariably result similar explosive waves, straining the engine without any useful effect.

Pressure Due to Explosion.—The pressure after exploding the charge will depend upon the amount of heat liberated and upon the weight of gas present. The amount of heat liberated by the explosion of the mixture of vapor and air will depend upon what fuel it is, whether kerosene, gasoline, or alcohol; the proportions of vapor to air; the amount of burnt gases left in the clearance, and the extent to which the charge has been heated on entering the cylinder during the suction stroke, and, finally, upon the compression pressure before ignition. It is easy to calculate this temperature rise on assumed values for these conditions, but it is just as easy to prove these assumptions wrong, so that computations of this kind are of no great value. Designers must, however, design an engine to resist these pressures, and so must have experimental values of this pressure. They are also valuable to experimenters in interpreting the performance of the engine by comparing the highest pressure observed in some case with the normal. If the normally high pressure is not attained, it has been due to an improper point of ignition, a loss in charge, or a weak mixture. The experimenter can also distinguish between normal pressure due to the heat liberated and abnormal ones due to explosive waves, which are de-

Gasoline is far different from a simple substance which would have a fixed boiling point, and therefore theoretical calculations on the heat of combustion, air necessary, and conditions for vaporizing or carbureting air are of little value. On the other hand, alcohol is a simple substance, or, more properly, there are many alcohols each of which is a simple substance; but they are not so used in an engine. The alcohol which it is proposed to manufacture for industrial uses under the recent law is ethyl alcohol having a definite chemical composition C_2H_5OH . This material is seldom, if ever, obtained pure, it being generally diluted with water and containing other alcohols when used for engines. The alcohol present is in an impure condition. Thus 90 per cent alcohol means alcohol and water mixed so that there is 90 per cent of alcohol by volume present. The density of the alcohol depends upon the amount of water present, of course, and upon the temperature as well, as it varies considerably with temperature. The Smithsonian tables of the density of alcohol with temperature are given here in part with a computation by which the percentage of alcohol by weight or volume can be determined when the density and temperature of the mixture are known.

For the range of percentage contained in the above table, the correction for temperatures different from 60 deg. F. should be made as follows:

Smithsonian table of specific gravities of ethyl alcohol.

Specific gravity at 60° F. compared with water at 60° F.	Percentage of alcohol—		Specific gravity at 60° F. compared with water at 60° F.	Percentage of alcohol—	
	By weight.	By volume.		By weight.	By volume.
0.834	85.8	90.0	0.822	90.4	93.4
0.833	86.2	90.3	0.821	90.8	93.7
0.832	86.6	90.6	0.820	91.1	94.0
0.831	87.0	90.9	0.819	91.5	94.2
0.830	87.4	91.2	0.818	91.9	94.5
0.829	87.7	91.5	0.817	92.2	94.8
0.828	88.1	91.8	0.816	92.6	95.0
0.827	88.5	92.1	0.815	93.0	95.3
0.826	88.9	92.3	0.814	93.3	95.5
0.825	89.3	92.6	0.813	93.7	95.8
0.824	89.6	92.9	0.812	94.0	96.0
0.823	90.0	93.2			

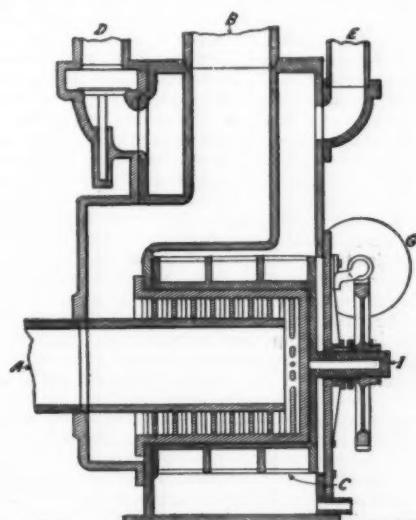


FIG. 6.—SECTION OF RETORT VAPORIZER.

structive to the engine bearings and metal parts, but not useful for producing work.

LIQUID FUELS.

The liquid fuels available for use in exploding engines—that is to say, for vaporizing and mixing with air in a properly constructed mechanism—have quite different characteristics. With respect to their source

If the density is measured at a temperature above 60 deg., 0.0005 should be added to the measured density for each degree which the temperature at the time of the measurement differs from 60 deg. When the temperature at the time of measurement is below 60 deg., the same correction should be subtracted from the measured density. The corrected density should then be used in the table for finding the true percentage of alcohol.

The percentage of alcohol found in a sample is always likely to be greater when determined chemically than when determined by the hydrometer, because the presence of impurities in the way of solids dissolved in the alcohol or as any of the series of higher alcohols tends to make the specific gravity of the sample greater, and hence make it indicate too low a percentage of alcohol.

Although pure alcohol is, as was shown above, a simple chemical substance, and so permits of computations on the heat of combustion, the amount of air necessary for its proper combustion, the amount of

heat to vaporize it, the proper air temperature for carburetion, or anything else that might be desired in connection with its performance in an engine, yet in actual engines this pure alcohol is never used. The revenue laws permit the tax-free use of only denatured alcohol, that is to say, a fuel consisting principally of ethyl alcohol, but with various substances added to it to render it unfit for drinking, and which may have little or much effect upon its value as an engine fuel. In the United States the substances to be added are at least 10 parts of methyl alcohol to 100 parts of 90 per cent ethyl alcohol by volume, in addition to one-half of 1 part benzine. Even this small addition makes it difficult, if not impossible, to make accurate calculations concerning what the mixed fuel will do in an engine. In Europe, during all these years of development, many hundreds of tests have been made with all sorts and conditions of fuel mixtures, some of them with alcohol which is free of denaturants, some with denatured alcohol, and some with purely experimental mixtures. Every different fuel element and every different fuel mixture will have characteristics when used in an engine, so that in comparing these engine results it is clearly necessary to have some knowledge of the nature of the fuel mixtures used.

HEAT OF COMBUSTION.

One of the most important things to know concerning a fuel is the amount of heat it will liberate when burned, or its heat of combustion, for by this the weight of fuel burned per horse-power hour can be transformed to thermal efficiency. This is determined practically by burning the fuel in a very accurate instrument called a calorimeter, so arranged that all of the heat will warm up water so that the amount of heat liberated may be determined by the temperature rise of this water. The heat of combustion, thus determined for the gasoline which we used in our tests, was found to be 21,100 B. T. U. per pound of gasoline. It is known that the heat of combustion of gasoline is not very different from that for the crude oil or any of the other distillates, and in common practice it is usual to take this value as 20,000 B. T. U. per pound of oil when other more accurate information is lacking. The alcohol which we used in our tests, 94 per cent by volume, had a heat of combustion as determined by the calorimeter of 11,900 B. T. U. per pound, which is just a little more than half that of the gasoline. The heat of combustion as determined by the calorimeter does not fairly represent the amount of heat set free in the engine cylinder, because when the fuel contains any hydrogen—and all of these fuels do—that hydrogen will form steam on combustion, which will condense to water and add its latent heat of condensation to the true heat of combustion. The heat of combustion obtained when the products are condensed, as in the calorimeter, is termed the high value; that obtained by subtracting from this high value the latent heat of condensation of such water as is formed is termed the low value. In reporting a calorific power for any of the oils or alcohol it must be clearly known whether the value is high or low, as they are appreciably different. Especially important is this when it is known that only the low value is set free in exploding engines, because the exhaust gases are always hot enough to prevent condensation of steam. These fuels contain carbon and hydrogen in various proportions and the alcohol contains, in addition, some oxygen. Knowing the heat of combustion and the elements, it would seem possible to calculate the heat of combustion of compounds of these elements, and various formulas have been proposed for this purpose which are used in some cases by European experimenters in reporting their results. It is interesting to note in this connection that the heat of combustion determined by such a formula from its ultimate analysis seldom gives values that agree with the calorimeter. This is because of certain assumptions made on the molecular constitution of the elements shown to be present. Thus, when hydrogen and oxygen are present in water proportions it is assumed that the group cannot give any further heat of combustion, and further, that there is no heat absorbed to separate the group from the other molecules as heat of dissociation. This assumption vitiates the results, but for any given fuel a constant can be determined in the nature of a correction to the calculation to make the results agree with the calorimeter, which it is possible to apply with fair accuracy to similar fuels.

AIR NECESSARY FOR COMBUSTION.

When a fuel has a definite chemical composition, the air necessary for combustion can be exactly determined; otherwise it must be an assumption. This calculation can be made, therefore, for ethyl alcohol or for methyl alcohol, but it is difficult, if not impossible, for a denatured alcohol or for gasoline or kerosene.

In an actual engine the amount of air is proportioned to the amount of vapor, not by any exact measurement of either, but by experimental trial, to secure either the best results in maximum power or minimum fuel consumption, but in this case the experimenter has no knowledge of the fuel supplied but unburned. As a check upon this adjustment, it has been the practice in the European tests, especially those of Sorel, to analyze the exhaust gases with a view to determining the amount of air supplied by the chemical composition of the exhaust. An engineer operating the engine, however, has no means for determining results such as this, and, in fact, cares very little just what quantity of air is being supplied so long as it is clear that no fuel is passing away unburned or so long as the engine is doing the proper amount of work with the minimum of fuel.

VAPORIZATION OF FUEL.

A device for preparing the mixtures in these engines, which performs three functions—vaporizing, mixing, and proportioning—is called a carburetor. Carburetors are universally used for gasoline and similar easily vaporized substances. Vaporizers in one form or another are almost universally used for kerosene, although some kerosene carburetors have been devised differing from the gasoline carburetor chiefly by the addition of a heating part. Alcohol is used in both of these devices—that is to say, alcohol carburetors are common and so are alcohol vaporizers, but the carburetors more common than the vaporizers. An alcohol carburetor may differ not at all from a gasoline carburetor, but by reason of the high temperature of vaporization of the alcohol some method of heating either the air or the mixture is necessary to insure complete vaporization, and the more water present the higher the necessary temperature. In order that the above distinction may be clear and variations in the detail design for accomplishing the same purpose may be set forth, descriptions of a few typical devices are given.

One common form of pure vaporizer in use in the West is a retort, of the class involving the dropping of oil on a hot plate. This is shown in Figs. 5 and 6. The exhaust from the main engine enters the retort at the port (A). The hot exhaust gases heat a central drum, around which the generating wheel revolves. The generating wheel (C) is a hollow wheel or drum, containing channels or buckets on the periphery. This wheel is driven by a belt from the main engine around a driving pulley (Fig. 6, G), transmitting power through a worm and gear to the driving spindle (I). The driving spindle is attached to the generating wheel, which revolves about one-half turn a minute. The heat radiating from the heated drum is intercepted by the generating wheel and utilized in transforming the oil into gas as it is fed into the channels of the generating wheel through the oil port (Fig. 5, F). As the oil is fed into the channels through the oil port it is carried up and over the top of the wheel, giving up its volatile parts by reason of the heat received from the wheel. The non-volatile portion of the oil, or the residuum, remains in the channels until they reach the bottom, where the residuum drops into a reservoir and is automatically drained off through the residue port by means of a pipe with a drop of 8 inches or more below the retort, having a horizontal check valve on the end. The check valve is for the purpose of keeping the residuum from being drawn into the engine cylinder. The exhaust gases are carried away from the retort by means of a pipe screwed into the flange attached to the exhaust outlet (Fig. 6, B). As the gas arises from the wheel to the gas chamber it circulates around a hot exhaust pipe, thus being superheated. It is immediately drawn into the main engine cylinder by the suction of the engine, through a connection of pipe and fittings from the gas port (Fig. 6, D), to the inlet to the engine cylinder, where it is ignited by whatever means may be used for that purpose. Air is also drawn by the engine suction into and through the retort case, entering at the air-inlet port (Fig. 6, E). In some cases the air-inlet pipe, connected to this port, runs about 2 feet and then turns down again. This is recommended to prevent gas from escaping through the air inlet between suctions.

There are no devices on the American market of the kind that specifically boils the fuel in a separate chamber. A device of this kind would have certain advantages over that of the simple hot-plate type for the following reasons: If the plate on which the oil is dropped gets too hot, the fuel will decompose, in addition to vaporizing, and leave on the plate a black, sooty residue. This is because these fuels are very sensitive to decomposing from overheating. If the plates are not hot enough, the fuel will be only partly vaporized, and good fuel will be thrown away as residue. When the heating is to be accomplished by the exhaust gases, not only must a lamp be supplied for initial heating, which takes a long time with such a mixing device as this, but further, and more important, the temperature of the vaporizing plates is very difficult if not impossible to regulate. On fluctuating load, therefore, where the engine requires more or less vapor from time to time the hot-plate vaporizer would sometimes be decomposing fuel from excess heat, at other times only partly vaporizing it, and in any case proportions of air to vapor will be sure to be irregular, so that in the mixture there will sometimes be an excess of vapor and sometimes an excess of air. Such a hot-plate vaporizer, therefore, is adapted only to those oils that cannot be otherwise treated in carburetors. For this reason retorts of this kind are almost solely confined to engines which use the crude oils.

Separate vaporizers as distinguished from carburetors are essential for kerosene and common for alcohol. They have been described at this point because the principles of their operation are simpler than those of carburetors and they are less numerous and less representative.

Carburetion is a process distinctly different from boiling. Air may take up the vapor of a liquid just as it takes up the vapor of water, even when the temperature of the liquid or the temperature of the air is very considerably less than the boiling point of the liquid. In short, air may take up some vapor at any temperature whatever, and it is not necessary that the liquid be brought to the boiling point. The amount of vapor which air can take up by simply coming in contact with the liquid depends upon the

vapor tension of the liquid and the pressure of the air. The air may be assumed to be always at atmospheric pressure, for the pressure in the suction pipe of an engine is but little less than that of the atmosphere. The amount of vapor that can be taken up from the liquid surface can be calculated quite exactly if the air is left in contact with the liquid long enough and if the liquid is a simple substance having a definite chemical composition and a definite vapor tension. The method is exactly the same as that used to compute the humidity of the atmosphere. Since gasoline is not a simple substance, such a calculation is impossible, but it is known by the practical operation of engines having carburetors that at ordinary atmospheric temperatures the air is quite hot enough to vaporize enough gasoline to make a proper explosive mixture and is in fact capable of absorbing quite a considerable excess of gasoline before it becomes saturated with gasoline vapor. There is, however, no difficulty whatever from the standpoint of air saturation in giving to the air sufficient gasoline vapor to make a proper explosive mixture for engines if the air be left in contact with the gasoline long enough, or if, in addition, the contact be of the proper sort. As gasoline consists of substances of different volatility, the mere contact of air with the surface of the liquid may not be sufficient to uniformly vaporize the mixture. The more volatile parts may come off first and there may be a residue which it will be difficult to vaporize. This difficulty was met with in the earlier carburetors and overcome in a way that will be explained presently. Alcohol being a simple substance, with a definite vapor tension, it is possible to calculate at what temperature dry air must be to contain sufficient alcohol vapor. If the air have any temperature higher than this, it is capable of carrying more alcohol than is necessary for a proper explosive mixture or capable of absorbing the amount of vapor necessary in a shorter time.

By a somewhat lengthy calculation it may be shown that dry air at a temperature of 72 deg. F., when saturated with alcohol vapor, has just enough of the vapor to form the theoretically best mixture for perfect combustion. If the air be moist, or the alcohol contain water, or the time allowed for vaporization be too brief, the temperature of the air must be higher than 72 deg. F. to form a proper explosive mixture.

As the engine does not use pure alcohol of this sort, but rather mixtures known under the general name of denatured alcohol, the corresponding temperature necessary to secure this proper vaporization will be different from that just given, but just how different cannot be stated. However, it is certain that air at any temperature will take up some vapor of alcohol and that the higher the temperature of the air the quicker it will take up the necessary amount for the best explosive mixture. In the case of incomplete vaporization some of the fuel may be carried along as spray, which may be vaporized in the cylinder on the compression stroke or may not, but if not then it certainly will be after the explosion of the rest. It would seem desirable, therefore, to quite considerably heat the air supplied to an alcohol carburetor; yet indefinite heating of the air will bring about a bad effect on the engine, because it will make the charge hotter at the end of compression, or, in other words, decrease the weight of the charge in the cylinder. The horse-power of the engine, other things being equal, will be decreased in direct proportion as the density of the charge is lowered by this heating, so that, on the one hand, heating of the air is good for complete vaporization, but bad, if carried to excess, in reduction of power.

EFFECT OF INITIAL COMPRESSION.

By rather involved mathematical calculation it may be shown that the theoretical efficiency of an internal-combustion engine depends upon the amount of compression given to the combustible mixture during the compression stroke of the piston. The greater the compression the higher should be the efficiency. In practice it is found that various causes operate to diminish the efficiency, thus tending to offset the benefits of high compression. Still, with good mechanism it is found that an increase of compression up to a considerable amount improves the efficiency.

With gasoline the compression can not be carried much above 80 pounds per square inch without danger of premature explosion of the fuel charge in the cylinder. With alcohol the compression may be safely increased to 200 pounds per square inch if desired if the engine is well cooled, and in numerous European engines 150 pounds have been regularly used.

HARDENING STEEL BY ELECTRICITY.

There are about sixty different methods of hardening steel, each of which has its advocates, and no one of which is suited for all sizes and shapes of articles, or for all kinds of steel. One way which has not yet come into general use is hardening by electricity, and is described by Garnier in *Le Genie Civil*. The process is simple and the appliances necessary neither complicated nor costly; neither is any great amount of previous experience in this particular manner of hardening required. The tool to be hardened is put in electric connection with the positive pole of the battery or other source of current; in similar connection with the negative pole there is a cast-iron tank full of carbonate of potash dissolved in water. The current is regulated by a rheostat. The tool is plunged to the desired depth in the solution, just as for hardening in the usual manner; the current is then switched on and the tool heated to the same degree

as would be required in ordinary hardening. When the proper temperature has been reached and held for the desired time, the current is switched off and the tool left in the bath, which latter, by the simple act of switching off the current, is at once converted into a hardening bath.

Another method, which permits of hardening places on the surface of pieces, where the dipping process would not accomplish the desired object, is local heating with the electric arc. Here the tool or other article is laid on a copper block, and an ordinary arc carbon held in a safety holder; the electric connections with holder and block being made, the carbon pole is touched to the piece to be locally hardened. Of course the heating is both intense and local; the work-piece is at once plunged in the ordinary hardening bath, and when one place is hardened the next may be heated, and so on. The electric current may also be used to draw the temper of a hollow object. Instead of using a red-hot iron rod to plunge in the bore, a cold rod is employed, which is used as a resistance in the circuit of a secondary current of about two volts tension. The temperature of the iron rod gradually rises, and when the work-piece has reached the desired color, the current is shut off. This method is said to produce less liability to cracking than the old-fashioned way of drawing the temper with a hot rod. It is particularly recommended for large hollow mills. The great advantage consists in the perfect regulation possible by means of a rheostat, and in the possibility of getting exactly the same temperature every time for similar objects, once the right heat and color are attained.

ELECTRIC EFFECTS PRODUCED BY LIGHT.

It has been repeatedly observed that if two similar metallic plates are immersed in a suitable liquid and then one of the plates is illuminated while the other remains dark, the light produces a disturbance at the illuminated plate and upsets the balance of the ar-

a small proportion of that due to light at a constant temperature. In these changes, the amount of chemical change is so minute that it would take about thirty years to separate by decomposition a milligramme of silver. Such an arrangement as described constitutes a true galvanic cell, but it differs from ordinary galvanic cells in being a galvanic combination only so long as it is exposed to light, and in gradually developing its maximum electromotive force in the presence of light, and gradually losing it when the light is withdrawn.

I do not know that these experiments have any obviously direct bearing upon current photographic practice. But the very essence of photography consists in partially illuminating a surface that is intended to be of a uniform character. The light causes a change, and it seems that all changes are accompanied by electrical disturbances. These experiments may help to show something of the character of the electrical changes that accompany the effects produced by "exposing" sensitive surfaces.—Knowledge.

PETROLEUM AND ITS REFINEMENT.*

By Prof. CHARLES E. MUNROE.

PETROLEUM, known also by other names, such as rock oil, mineral oil, coal oil, or earth oil, is an oily liquid, varying in color from light straw through amber, red, and brown to black. Existing in the earth, it is obtained from either springs or wells. Petroleum is distributed widely, and its existence was known to the ancients. The aborigines were familiar with many localities in North America where it issued from the ground and spread out on the surface of the water in contiguous pools, creeks, and rivers. The oil spring of the Seneca Indians, located near what is now Cuba, N. Y., was one of the more celebrated of these springs, and the oil collected there was used for medicinal purposes.

Although a natural product, petroleum is not a defi-

in the proportion of these series and the members of the series." However, from a commercial standpoint, petroleum from different localities is regarded as different substances, and the products are referred to and considered from the standpoint of some predominating or characteristic constituent. Thus, Pennsylvania petroleum is classed as an oil with a paraffin base; Texas and California petroleum, as oils with an "asphalt" base; petroleum from the Lima field in Ohio, as a sulphur oil; and so on as the characteristics are developed.

Although petroleum as found in nature, and therefore styled crude petroleum, has in recent years come to be used extensively in locomotives and ships, and for metallurgical, manufacturing, and domestic purposes as a fuel, and although other uses have been found for it, such as oiling roads, coating piles, and exterminating insects, yet for the majority of purposes petroleum must be treated before use to adapt it to the special purpose to which it is to be applied, and this treatment constitutes the industry known as petroleum refining. The processes employed in petroleum refining are many in number and different in degree of complexity. The particular process used in any given case is determined by the character of the petroleum to be treated and the character of the products sought. In the case of the more complex processes a method of treatment suitable for a crude petroleum from one locality is poorly adapted or wholly unsuitable for the treatment of crude petroleum from another. The processes of refining may be roughly classified as follows: Treatment by settling to remove suspended matter and water; filtration; fractional distillation; destructive distillation; and, subsequent to or combined with the processes of distillation, the treatment of the distillates, known as fractions, with acids or alkalies, or both, and sometimes with other chemicals; also, treatment by chilling, pressure, and filtration.

The cleaning of crude petroleum by settling is the process used in the case of heavy, viscous oils found in loose sand of great fineness, since the sand and water



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angement. The two plates become dissimilar, and therefore an electric current is produced in a wire that joins them. Becquerel and Minchin, in their investigations of such effects, found such irregularities in their results that they failed to establish any general principle, and supposed that there existed some obscure surface action, so that it appeared as if light in this case was not comparable to other forces, such as heat. Dr. M. Wilderman has recently been working at the same subject, under probably more stringent conditions than the previous investigators, and he finds that light and heat are strictly analogous, that irregularities previously noticed were due to polarization of the electrodes, or possibly sometimes to insufficient care in getting them perfectly balanced before the experiment. For however carefully two silver plates, cut from the same sheet of the purest metal obtainable, are annealed and polished, it may be necessary to keep them in the liquid for one or two days, or even more, before they are sufficiently alike to produce no electromotive force of the order of intensity observed in these experiments when both remain in the dark. When light, as from an acetylene flame or an electric arc, is allowed to impinge upon one plate of such a balanced system, an electromotive force is produced which is due partly to a rise of temperature, and partly to what Mr. Wildermann calls "light at a constant temperature." Of course, radiant energy of a given wave length is not supposed to be divisible into two parts of different characters, but it seems that the disturbance it causes shows itself partly as heat, which in turn produces an electromotive force, while part produces an electromotive force directly, without the intervention of heat. The word "light" is rather an unfortunate term in this connection, because, as commonly understood, it is an effect upon the optic nerve, and the limitations of the sensitivity of our eyes do not enter into this matter at all. When a red screen was interposed in the path of the light, the resulting red light gave about three-fourths of the heating effect of the unshielded light, and only

nite chemical compound. It consists of a mixture of various hydrocarbons from several different acyclic and cyclic series, and of hydrocarbon derivatives containing sulphur, or oxygen, or nitrogen, or other elements. These chemical substances have widely varying physical properties and appearances, differing in color, odor, volatility, viscosity, inflammability, specific gravity, boiling and freezing points, and in other particulars; hence mixtures of them in different proportions will appear quite unlike. Furthermore, the components in such mixtures are held together so loosely that they may be separated, more or less completely, by comparatively simple methods, such as filtration, and especially capillary filtration, through fuller's earth, kaolin, boneblack, or other finely-divided and porous solids, or by fractional distillation. Therefore, considering the conditions which affect the natural material in different localities, it is not surprising that the varieties of petroleum obtained in Texas, California, and Ohio should differ in appearance and properties from each other and from the better-known Pennsylvania petroleum; or that in Kansas petroleum may be obtained which is immediately suitable for use as an illuminant, while in West Virginia petroleum is found which is suitable for use as a lubricant without undergoing any preliminary treatment.

If the survey were extended to include the petroleum found in foreign countries, such as Canada, Russia, Burma, and elsewhere, additional variations might be noted, yet Mabery, who has exhaustively examined a large number of samples from widely different sources, says:† "Now, after these years of arduous labor, I have reached the conclusion that petroleum from whatever source is one and the same substance, capable of a simple definition—a mixture in variable proportions of a few series of hydrocarbons, the product of any particular field differing from that of any other field only

become mixed with the oil and are pumped up with it. An example of this method is found in the practice obtaining in the Kern River field of California, where great difficulty is experienced from sand. It is customary there to pump the oil into small excavations made in sandy soil as close to the well as possible. These holes, called "sumps," are originally of from 500 to 2,000 barrels capacity, but they rapidly become shallower from the deposits of detritus from the oil. From the sumps the oil flows by gravity to storage reservoirs, which are shallow excavations made in the soil and covered with light wooden roofs. These reservoirs are often of great size, and it is customary to carry in them as large a quantity of oil as possible, in order that the sand may settle and the water separate completely. During the summer months the oil is continually at a high temperature and becomes clean by this simple treatment. During cooler weather, or whenever the reservoir purification is thought insufficient, the oil, before shipment, is passed through a small steel tank provided with steam coils, where it is heated for a sufficient time to remove these impurities. The degree of temperature, which is from 110 deg. to 150 deg. F., and the duration of time, which is usually only a few hours, are determined by the specific gravity of the oil and the amount of impurities it contains. According to Prutzman,* "The high degree of purity which is obtained by the use of these simple methods is quite astonishing. Even where the impurities originally amount to 50 per cent of the bulk of the crude oil, which is often the case, the oil finally shipped will not contain more than 2 per cent of foreign matter of all kinds, and the larger part of the fuel oil in the San Francisco market, at least, will be found to contain less than 1½ per cent of impurity." This treatment results in other advantages, for the gas with which the oil is charged as it comes from the well, and which affects its gravity and flash point, is also very largely removed. It is interesting to note that when oils, such

* Abstracted from Bulletin published by the Census Bureau of Manufactures.

† Journal American Chemical Society, 1906, vol. xxviii, page 417.

as these heavy crude oils, are exposed in shallow pools to sunlight in hot climates the oil is so oxidized that its gravity is lowered while its viscosity is raised, and the oxidation may proceed so far as to convert the oil into a tarry mass. If the dissolved gases be removed from the oil and sunlight be excluded, the effects of high natural temperatures are not serious, and it thus becomes possible to store oil for considerable periods in such reservoirs. Although the oil has been distinctly improved by methods of purification, such as described, the product is not considered as refined oil in the Census classification and the establishment in which the operation is carried on is not included with refineries.

Filtration was resorted to for the purification and refining of petroleum, especially in preparing it for use in medicine, at a very early date. Dr. Hildreth in 1833 mentions^{*} filtering petroleum through charcoal, by which process much of its "empyreumatic smell is destroyed and the oil greatly improved in quality and appearance." Since then a large number of different substances have been employed as filtering mediums to remove from crude petroleum all sediment and suspended matter, together with part of the color and odor. Since the development of refining by distillation, filtration for the removal of color and odor has been confined largely to the denser natural oils which are used for the production of lubricating oils and which may lose some of the qualities that especially fit them for this purpose, if subjected to the conditions which obtain in the process of distillation. Crude oils which contain lubricating oils, but owing to the presence of volatile portions are too fluid for direct use, are reduced to the desired consistency by partial evaporation, either by exposing them in shallow tanks to solar heat, or by driving off the more volatile portions in stills, or both, and they may be further cleansed and purified before or after concentration by filtration.

Partial distillation is employed in the production of reduced oils. This process requires the use of shallow wooden tanks on the bottom of which flat steam coils are placed; water is run into the tanks to a depth of from 8 to 10 inches, and a layer of oil 1 inch in depth is placed upon the water; the whole is then heated until the oil becomes very limpid, and this temperature is maintained until the desired specific gravity is reached. An advantage in this treatment, as in the method of settling described above, lies in the removal of every kind of dirt, especially the minute particles of grit which may have been held in suspension in the viscous oil, and if allowed to remain would seriously detract from the value of the reduced oil as a lubricant. Another method practised in the manufacture of reduced oil consists in suspending sheets of loosely-woven cloth vertically above troughs in a heated chamber, and through a perforated pipe spraying the crude oil upon the upper edge of these curtains. As the oil slowly descends the curtain it spreads out as a thin film, thus exposing a very large surface to the heated atmosphere of the chamber; and thereby the more volatile portions of the oil are rapidly driven off. At the same time the fiber acts as a filtering medium, retaining the sediment and other impurities of the crude oil, so that the surplus oil, as it drips from the lower border of the curtains into receiving troughs, is not only reduced and rendered more viscous but is also purified and cleansed.

The process of refining by fractional distillation depends primarily upon the fact that different liquids, when subjected to the same pressure, boil at different temperatures, from which it might be inferred that if a mixture of different liquids were heated gradually,

each component of the mixture as it reached the temperature at which it boils would assume the state of a vapor and separate from the mixture. If only these simple conditions obtained, the separation of a liquid mixture into its individual components could be effected merely by heating the liquid to the successive boiling points of its components, and condensing and

a mixture of two or more vapors when condensed will yield a liquid richer in the more volatile constituent." By repeating the distillation of the separate fractions and uniting those obtained between the same boiling-point limits, a practically complete separation may eventually be effected. But if, on the other hand, the two components of the liquid taken as an example



BIRD'S EYE VIEW OF ECLIPSE WORKS.

collecting the distillates. But the conditions are not so simple, for the separation of components of solutions by heat depends not only on their relative boiling points, but also on their relative vapor pressures, and vapor pressures change with the temperature. Further, the most complicated conditions arise where, as in the case of crude petroleum, the mixture consists of liquids which dissolve one another, that is, are miscible in each other, and the complexity increases with the increase in the number of components. The case may be stated for a system of two miscible liquids as follows: Such a mixture on being heated is continually changed in composition during vaporization, and this brings about a change in the pressure and the composition of the vapor. If the two components have very different vapor pressures and their boiling points are correspondingly wide apart, the vapor pressure and boiling point of the mixture usually fall between those of the components, and under these circumstances the more volatile liquid goes over in the largest proportion in the first stages of the distillation, while the greater portion of the less volatile liquid remains behind. The separation is not, however, complete. The liquid mixture has been divided into portions, called fractions, but each fraction still contains some of each constituent. It has obeyed the law stated by Barker:^{*} "Since at the same temperature the vapor pressure of a liquid is proportional to its volatility,

have vapor pressures and boiling points which lie near together, one of two other consequences may follow. The mixture behaves similarly to one composed of liquids not completely miscible, and the vapor pressure of the solution is greater than that of each of its components. In this case there must be a certain ratio between the two pure liquids at which the common vapor pressure will attain its highest value. This mixture will consequently have the lowest boiling point of any possible combination of these two substances, and it will, on distillation, behave like a pure substance with a constant boiling point and distill over, leaving in the still the substance which is in excess with respect to this boiling-point mixture. On the other hand, the mixture of the two liquids may have a lower vapor pressure than that of either component. Such liquids must form, in definite proportions, that mixture which has the lowest vapor pressure and the highest boiling point of any possible mixture of these two substances, and on distilling the liquid, anything present, for example an excess of one of the components which is more volatile than this definite mixture, passes over first, leaving in the still the mixture with the highest boiling point, which behaves much like a single substance, and distills without separating into its components.

The distillation of crude petroleum is usually carried out in either cylindrical or "cheese box" stills. The size and the arrangement of these stills and the method of heating them vary with the character of oil to be treated and the products sought. The cylindrical still consists of a cylinder of boiler plate, 30 to 40 feet in length and 12 feet 6 inches to 14 feet in diameter, the lower half of which is usually of steel. The still is set horizontally in a furnace of brickwork, which is usually so constructed that the upper surface of the still is exposed to the air. Stills are often set in batteries of from two to ten for convenience in operation. The "cheese box" still has a body and a dome-shaped top made of boiler plate, and a double curved bottom made of steel plate. They may be 30 feet in diameter and 9 feet in height, and they are set vertically on a series of brick arches. The working charge of the cylindrical still is from 600 to 1,000 barrels, and of the cheese box still, 1,200 barrels.

Either form of still may be heated by direct fires or by coils of steam pipes, either closed or perforated, which may be fitted into the stills to heat the oil, or by the injection of steam to facilitate, on the principle of partial pressures, the passing over of the distillates. Some stills are connected with an exhaust pump by which a vacuum may be maintained in them during distillation. The top of the still is usually provided with a dome into which the vapors rise and from which they pass to the condensers. The condensing apparatus consists primarily of long coils of pipe immersed in tanks through which cooling water flows. All the coils or lines are made to converge near the terminal so that they enter the receiving house within a few inches of each other. A trap is placed in the pipe near the end of each line for the purpose of leading off the gases or difficultly condensable vapors which are produced, and these are either collected for fuel or discharged into the atmosphere. The condensing pipes generally deliver the distillates into box-like receptacles, sometimes known as "sight boxes" because they have sides of plate glass through which the running of the distillate may be observed. Hydrometers,

* American Journal of Science, vol. xxiv., Series I, page 63.

* George F. Barker, Physics, 1892, page 318.



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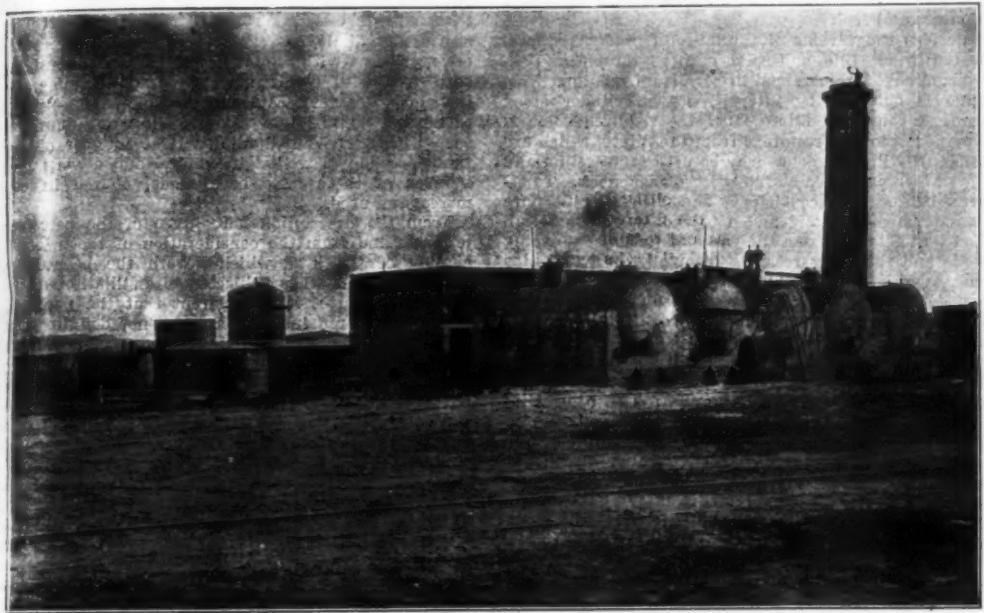
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by which the density of the distillate may be noted, and thermometers, for determining its temperature, are immersed in the flowing liquid or in samples of the run which may be taken from time to time for testing. As the character of the distillate changes, the delivery pipes from the condensers are turned to different receptacles. The receptacles lead to storage tanks or reservoirs, sometimes styled "cut tanks."

In addition to the above stills there are in use what

stillate, while tar coke is left in the still. The first of the above distillates is wax bearing, and in the last part of its run this distillate is known as wax tailings; the third consists largely of illuminants, while the second distillate is of an intermediate character. All are joined to analogous materials passing through the refinery and are reworked by methods similar to those described above.

Oils that are to be subjected to chemical treatment



STILLS FOR CRUDE PETROLEUM.

are known as tar stills, which are made of iron or steel and are cylinders 10 feet in diameter and 20 feet in length. They are set horizontally in brickwork in batteries of two and are heated by fire. They hold about 260 barrels, and are provided above with air condensers leading from a dome in the center of the top of each cylinder. The condensers are of 4-inch iron pipe coiled in three turns one above the other in a rectangle of about the length and width of the still. As the coil makes one complete turn, it is trapped to carry off the products which have condensed at that stage.

As stated, the process of distillation varies with the circumstances, but the operation may take place as follows: The oil is first allowed to stand in large tanks so that part of the water and sediment are removed before it is pumped to stills into which live steam is introduced. Distillation commences at once and the distillate is collected in a receptacle continuously until its specific gravity reaches 0.74 (60 deg. B.). The condensers are now connected to another receptacle, and as the temperature rises and distillation proceeds the distillate is collected until its specific gravity reaches 0.81 (40 deg. B.). The heavy oil which remains is often distilled with superheated steam for the production of lubricating oil. The first original distillate is redistilled by steam and separated, commonly, into five different fractions. The second original fraction may be subjected to a second distillation to drive off lighter oils, which are then added to the first original fraction. The third original fraction may be chilled so as to cause the paraffin present to crystallize. The semi-solid mass of paraffin thus produced is then subjected to pressure to drive out the oil which is present. This oil is further subjected to the action of steam in a still to remove from it certain oils which possess a pungent and offensive odor. The distillates are then subjected to chemical treatment or to filtration, or to both if further refining be desired.

It was noted long ago in the making of coal gas that if the less volatile products from the distillation of the coal were allowed to condense and fall back into the hot retort, the liquid was decomposed into other substances, some of which were much more volatile than the original condensation product. This process of breaking up an organic liquid by heat is called "cracking." It is a process of destructive distillation and may be applied to many substances. It has long been applied to the treatment of petroleum, for by its use a larger portion of illuminants and oils of low boiling point may be obtained from a crude petroleum than is usually obtained by simple distillation only, since in the latter case a large per cent of the petroleum may remain as heavy oils or paraffins. In this process the operation of distillation is carried out as before, using fire, but when the second original fraction has been separated and collected, the fires are slackened and the distillation allowed to proceed slowly, in consequence of which the vapors of the heavy oil are repeatedly condensed upon the dome of the still and fall back upon the hot oil beneath, with the result that there is produced a large volume of gas, composed chiefly of marsh gas and hydrogen; a distillate of suitable specific gravity for the production of illuminating oil; and a heavy, tarry residue, called "residuum," which remains in the still. This residuum goes to the tar still, where, on further distillation by fire, there is collected at the first trap heavy distillate, at the second trap intermediate distillate, and at the third trap light dis-

to improve their color, or to remove components which might interfere with their use for particular purposes, are pumped from the cut tanks into the agitators. The latter are narrow upright cylinders with conical bottoms, generally lined with sheet lead and provided with an air blast descending from above and with outlets below for the spent chemicals and the treated oils. Agitators may hold 50,000 gallons of oil at one charge. The reagents usually employed are concentrated sulphuric acid and caustic soda or other alkalies. The sulphuric acid forms sulphonate acids, and addition and other compounds with the unsaturated hydrocarbons, through which they become soluble in water, and may be removed. At the same time other of the components of the oil are oxidized, so that, as a result of the reaction, when the oil is mixed with acid by means of the air blast, the mixture becomes thick and black and there is an evolution of sulphur dioxide. The mass is allowed to stand and thereby separates into layers of oil and spent or "sludge" acid. The latter is drawn off and the oil washed by agitation with water. It is then treated with an alkaline solution, by means of which not only any free sulphuric acid but also any acid salts or other bodies present may be neutralized. After the alkaline solution has settled and been drawn off, the oil is washed until all traces of alkali are eliminated, and then it is drawn off to settling or sunning tanks. In special cases it may now be again distilled to fraction it more completely, or it may be treated in a steam still to reduce it.

The quantity of sulphuric acid required in refining petroleum and the length of exposure to its action depend on the original purity of the distillate and the purity sought. Cracked oils require more acid than uncracked, and the Ohio oils require more than the Pennsylvania. Usually the amount of acid required increases with the density of the distillate. It is, as a rule, added in repeated doses until the desired result is obtained. The acid sludge is sometimes treated so as to regain the sulphuric acid for reuse; at other times it is used in the manufacture of fertilizers and for other purposes in chemical manufacture.

In 1905, 165,104 short tons of sludge acid, having a value of \$400,480, or \$2.43 per ton, were reported as having been sold from the refineries. The weight of sludge acid thus accounted for formed 78.1 per cent of the total sulphuric acid used in refining in that year. In 1890 there were reported 33,911 tons of sludge acid used for fertilizers and chemicals, and 19,962 tons for recovered sulphuric acid, the total, 53,873 tons, constituting 56.1 per cent of the total sulphuric acid reported as used in refining petroleum at that census. In 1880 there were reported 22,163 tons of sludge acid used for fertilizers, and 21,159 tons for recovered sulphuric acid, the total 43,322 tons, constituting 94.5 per cent of the total sulphuric acid reported as used in refining petroleum at that census. The alkali sludge has sometimes been heated to destroy the organic matter present and recover the alkali, but this is usually found unprofitable.

When sulphur is present in petroleum, it is difficult of removal, so that special treatment must be given oils, such as Lime oil, which are high in sulphur contents. Some refiners effect this by distilling the petroleum over scrap iron and treating the distillate first with an alkaline solution of lead oxide, and then with flowers of sulphur to remove the last traces of lead. Much the greater part, however, is distilled over copper oxide, the oxide being regained by burning off the sulphur.

According to Mabery,* "Probably 50 tons of sulphur daily is a conservative estimate of the amount extracted from Ohio oil and burned off into the atmosphere. It is claimed for this process that it is capable of removing the sulphur to two one-hundredths of 1 per cent, which is probably correct." In addition to the chemicals mentioned, others are sometimes used, among which are chromic acid or bichromate of potash and sulphuric acid, employed to oxidize the acidic and objectionable components; nitronaphthalene, added to the oil prepared for sale to mask the phenomenon of fluorescence, or to deblow the oil; and many others mentioned in the patents on petroleum refining.

The classification of petroleum products is a matter of difficulty because the same name has at various times been given to different substances, some of which are not products of petroleum, and because the same material has been known by different names. The different products may, to some degree, be differentiated by their boiling points, specific gravities, and fire tests. Yet again there is confusion from the use, for liquids lighter than water, of the Baumé hydrometer, which has a purely arbitrary scale, with which to gage the densities of the oils, instead of one which would measure their real specific gravities directly, so

* Journal of the American Chemical Society, 1906, vol. xxviii., page 452.



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that a 60-deg. oil on the Baumé scale is one whose real specific gravity is 0.745, while a 48-deg. B. oil is one whose real specific gravity is 0.794; in other words, the higher the number on the Baumé scale, the lower is the real specific gravity and the lighter the oil. Likewise, the fire test, or test of the behavior of the oil on exposure to a naked flame or source of ignition, covers both the flashing point test, for determining the lowest temperature at which the oil gives off vapors which form combustible and explosive mixtures with air, and the burning point test, for determining the lowest temperature at which the body of oil will take fire and continue to burn. It is greatly to be regretted that this confusion exists in the literature on the subject, and particularly in the statute books, as the flashing point test is the one by which the community is protected from accidental explosions and fires in the handling and use of illuminating oils.

With this introductory explanation, it may be stated that the term "naphtha and gasoline" embraces pentane, boiling point 100.4 deg. F., real specific gravity 0.625, which is used as a standard of light in photometric work; petroleum ether, boiling point 104 deg. F. to 158 deg. F., specific gravity 0.65 to 0.66 or 85 deg. to 80 deg. B., which is sometimes known as Sherwood oil, and is used as a solvent for caoutchouc and fatty oils, and for carbureting air in gas machines; 76-deg. gasoline, boiling point 159 deg. F. to 194 deg. F., specific gravity 0.66 to 0.69 or 80 deg. to 75 deg. B., known also as 680 spirit, motor spirit, petrol, carburetor, and boulevard gas fluid, and used in naphtha lamps and internal combustion engines, in the extraction of oil from seeds and fat, from garbage and wool, and in carbureting water gas; naphtha, boiling point 177 deg. F. to 230 deg. F., specific gravity 0.69 to 0.70 or 76 deg. to 70 deg. B., known also as Danforth's oil, ordinary spirit (when in the condition of untreated distillate), deodorized spirit (when purified), and city naphtha, and used as petrol in motor cars, for burning in vapor stoves and street lamps, as a solvent for resins in making varnishes, and in the manufacture of oilcloths; stove naphtha, specific gravity 0.70 or 70.4 deg. B.; lignoin, boiling point 176 deg. to 248 deg. F., specific gravity 0.71 to 0.73 or 67 deg. to 62 deg. B., used as a solvent in the chemical laboratory and in pharmacy and for burning in sponge lamps; benzine (deodorized), boiling point 248 deg. to 302 deg. F., specific gravity 0.73 to 0.75 or 65 deg. to 57 deg. B., used as a substitute for turpentine for cleaning printers' type, and for dyers', scourers', and painters' uses. In the refinery all of the above-mentioned fractions may be included in the substances known as A-naphtha, specific gravity 0.74 or 64 deg. to 60 deg. B.; B-naphtha, specific gravity 0.72 or 68 deg. to 64 deg. B.; and C-naphtha, specific gravity 0.70 or 80 deg. to 68 deg. B. All petroleum distillates having a specific gravity above 60 deg. B. may be styled "naphtha and gasoline." Although engine distillates which are a cut between "naphtha and gasoline" and kerosene, may be classed with the former, the lightest engine distillates, which run well up in the sixties in gravity, are prepared for small engines, while the heaviest are intended to replace kerosene in kerosene engines. As a rule they are not as carefully purified as gasolines and kerosenes of the same gravity and differ, in the lower members, from kerosene in that no attention is paid to the flashing point.

The distillate collected between 60 deg. B. and 40 deg. B., or specific gravity 0.744 to 0.829, is crude illuminating oil. The refined illuminating oils are known by a large number of names, the most common general name being kerosene. The oils are graded by their color, their flashing point tests, their burning point tests, and their specific gravities. Water white oil of 120 deg. F. flashing point test, 150 deg. F. burning point test, and 48 deg. B. gravity is standard, but there are many other gravities of water white oil. The Quartermaster's Department of the army has specified 135 deg. F. flashing point as the minimum for oil supplied to that department. Other grades, by color, are prime white, having a faint yellow color, and standard white, having a pronounced yellow color. Water white oil of gravity 45.5 deg. B. and 175 deg. F. burning point is frequently sold as headlight oil for use in locomotives. Water white oil of 36 deg. to 38 deg. B. and 300 deg. F. burning point is known as mineral sperm oil, mineral seal oil, mineral colza oil, coach oil, and 300-deg. oil, and is used as an illuminant in railway coaches and lighthouses, and for other purposes where readily ignitable oils are objectionable. Such an oil produced from wax oil, when pressed, and not lighter than 34 deg. B., is used in Pennsylvania in compounding miners' lamp oil. An oil having a specific gravity of 0.85 to 0.86 and a flashing point above 100 deg. F. is known as gas oil. Stove oil is generally a cut from the crude still following the kerosene.

The lubricating oils vary so greatly as to be beyond description within reasonable limits. All should have high burning points, and a natural lubricating oil to be of real value must not ignite under a temperature of 325 deg. F. The lightest of the lubricating oils, varying in gravity from 32 deg. to 38 deg. B., are known as neutral oils, or when further purified by filtration through boneblack or fuller's earth, as they usually are, as neutral filtered oils. Heavier lubricating oils are styled "spindle oil" and "cylinder oil." The most important characteristics which distinguish these oils are high burning point, and viscosity, and low cold test. Cylinder oils are obtained by distilling the heavy oils, from which the naphthas and illuminating oils have been removed, with superheated steam, taking care that no cracking takes place. Or they may be produced by distillation in a vacuum. Paraffin

lubricating oils are obtained by chilling the first distillate from the tar stills or other wax bearing distillates, these being chilled in the chilling house by cold brine from an ammonia ice machine. The chilled mass is pressed to separate it into paraffin and oil, and this oil is then redistilled and cut into several fractions. The common cuts for paraffin oil are one of 29 deg. to 30 deg. B., and a heavy cut of 23 deg. to 26 deg. B. To give the oils higher burning points and viscosities, they are cut from one-half to one degree higher than wanted and then reduced in a reducing still by means of steam and fuel.

Besides the various oils, semi-solid products, represented by vaseline, and solid, such as paraffin and petroleum coke, are obtained in petroleum refining. Vaseline is obtained by filtering heavy cylinder stock through boneblack filters until the required color is obtained; the first runnings from the filters, which are sufficiently light in color, may be used for vaseline, and the darker part used as filtered cylinder stock. To secure the necessary consistency and melting point, pure paraffin is melted and added to the filtered material. Rod wax obtained from the tubes and rods of pumping wells and the salvy residues from oil tanks and pipe lines, which is known in the industry as B. S., are employed in the manufacture of these semi-solid petroleum products. They are used directly as ointments or employed with drugs in the manufacture of ointments and salves, and are styled in the United States Pharmacopeia *Petrolatum molle*, or soft petrolatum, the requirement being that they have a melting point of from 104 deg. to 113 deg. F. If the rod wax be pressed, it yields a solid with a low melting point and a salvy half-paraffin nature, which, either directly or when mixed with chicle or balata gum, is used as chewing gum. Paraffin, obtained from the chilling and pressing of the wax bearing distillates, preferably distilled at high temperatures to insure crystallization, is generally manufactured in three varieties, with melting points of 125 deg. F., 128 deg. F., and 135 deg. F., known as C, B, and A paraffin, respectively. The *Petrolatum spissum*, or hard petrolatum, of the United States Pharmacopeia, should have a melting point of from 113 deg. to 125 deg. F. Thus petroleum paraffin stands next in the order of petroleum products as classified by the melting points. The paraffin is purified by chemical treatment like that for the other distillates, by filtration to remove color, by recrystallization from solution in benzine, and by sweating. This last is done by chilling it in cakes in shallow trays having wire-mesh bottoms. These are stacked in rooms, which are gradually heated. The paraffin, having the lowest melting point, becomes liquid, drips out, and is collected; with another increase in temperature and change of receivers the paraffin of the next higher melting point is obtained, and the operation is thus continued until the desired degree of separation is effected.

Paraffin is used for many purposes in the arts. The harder varieties are used largely in the manufacture of candles, about 5 per cent of stearic acid being added to prevent the candle from softening and bending. They are used also for finishing calicoes and woven goods and in laundry work to produce a luster. The softer varieties are used for coating jellies and fruits in preserving jars, for the preparation of translucent and waterproof paper, for waterproofing cloth, for mixing with stearic acid and wax in candlemaking, for impregnating the wood of Swedish matches, and as the absorbent in the process of enfeuage or extraction of the perfume from flowers.

Residual pitches are obtained in the distillation of the "asphaltic" petroleum of California, the "semi-asphaltic" petroleum of Texas, and of some paraffin petroleum. The residues from California petroleum have been used to a considerable extent in the paving industry and are generally known as "D" grade asphalt or by some special trade designation or brand. According to Richardson* this "D" grade asphalt, when properly made, contains not over 10 per cent of fixed carbon, while the asphalt from Texas oil contains a higher percentage of this constituent. The more liquid portions of these residues are used in compounding sheet asphalt, in which they constitute from 12 to 50 per cent of the composition. For this purpose, California oil should be from 10 deg. to 13 deg. B.; Texas oil, 14 deg. to 16 deg. B.; and Eastern oil, 18 deg. to 22 deg. B.; and all should have a flashing point above 350 deg. F. to be suitable for use.

Other petroleum products used in the paving industry are Pittsburg flux, produced by heating a gallon of ordinary Pennsylvania petroleum residuum with about 1 pound of sulphur; Ventura flux, made by treatment of the California residuum in a similar manner; byerlyte, formed by oxidizing Pennsylvania residuum by sucking air through it, Byerly of Cleveland having found that oxygen, like sulphur, effected a condensation of the residuum; and hydroline B., produced by blowing air through the "asphaltic" residuum from Texas petroleum. These substances are prepared for use as fluxes for native asphalt. By blowing the crude oil with air similar oxidation and inspissation takes place. If the oil be warmed at the start, the oxidation not only maintains the temperature but causes it to rise to as high as 900 deg. F. Water vapor is evolved, though but little, if any, of the more volatile components of the oil are driven off. The blown residues thus formed are used for waterproofing, for paints, for rubber substitutes, and for use in the arts. Residua are used in oiling dirt roads. Petroleum coke, which is the porous, brilliant black solid left in the tar stills,

is used in the manufacture of electric light carbons.

Greases are semisolid to solid products used in lubrication. They are usually made by mixing a lime soap with a petroleum distillate. A rosin-lime soap and mineral oil produce axle grease or set grease, and a mixture of lime soap made from horse fat or cottonseed oil with mineral oil is styled "engine grease." Both may be mixed with lead oxide, mica, soapstone, or graphite. Wax tailings are used on the rolls in iron and tin-plate mills under the name of roll grease. Compounded oils are produced by mixing mineral oils with animal oils, such as neat's-foot, lard, tallow, sperm, and whale, or vegetable oils, such as rape-seed, olive, or palm, with soaps, such as lead and aluminum soap, and with solids, such as graphite, mica, and soapstone. A very common oil, known as mineral castor oil, is made by compounding an aluminum soap with petroleum distillate. The number of mixtures possible is well-nigh infinite, and a very large number of these have been made, offered in commerce, and used.

From the description here given of the petroleum products and from the consideration of the brief discussion of the laws which govern the behavior of miscible liquids when subjected to distillation, as previously set forth, it is apparent that the petroleum distillates offered in commerce are not definite chemical compounds, or even definitely compounded and constant mixtures. Although, by the use of the hydrometer and thermometer, fractions may be obtained having within limits similar specific gravities and boiling points, yet it does not follow that two distillates possessing these characteristics are otherwise similar, and observation of such distillates from different localities shows them to be different. It follows then that the general trade names only roughly designate the different distillates, and that a desired distillate must be carefully described in specifications by its physical and chemical properties. It is evident too that the process of refining requires much distilling and redistilling, with compounding of the distillates between redistillations, to obtain the maximum quantity of a desired product from the crude petroleum, and that these processes will vary in kind and number with the particular crude petroleum treated and as to whether or not cracking is resorted to. When there is added to these the employment of fire, or low-pressure steam, or high-pressure steam, or a vacuum in the processes of distillation and the variations in chemical treatment and filtration, it is apparent that no general description of the process of petroleum refining can set forth the operations of the different individual factories except in a very broad way.

The transportation and storage of petroleum products, and more especially of the lighter distillates, are of great public concern, since they have frequently given rise to accidents, owing to the fact that they freely give off, at the lowest natural temperatures, volatile inflammable vapors which form explosive mixtures with air. The liquid distillates are transported on a large commercial scale, in bulk, in pipelines, tank cars, and tank ships, to distributing points, from which they are delivered in tank wagons, barrels, and cans to small consumers. Probably the larger part of all the lighter distillates produced are distributed in tank cars, which consist of cylindrical steel tanks mounted on their sides on platform cars. They vary in size, but are frequently 25 feet long by 6 feet in diameter and carry about 8,000 gallons of distillate. They are provided on the upper side with a covered manhole, through which they are filled, and a safety valve to diminish the liability to explosion in case of fire. For shipment abroad, oil is put in rectangular tin cans holding 5 gallons each, and two such cans are packed in a wooden case. As examples of the hazard attending the transportation of petroleum products, there may be cited the explosion at Rochester, N. Y., December 21, 1887, following leakage from a pipe line across that city, and the fire and explosion at the Sheraden Yard, Pittsburg, Pa., May 12, 1902, following the collision of other cars with a tank car in making up a train. The liquid distillates are generally stored in steel tanks above ground. These should be provided with safety valves or screened ventilators and should be surrounded by screen walls of such construction and height, or should be partly sunk in an excavation or pit, in such manner that the inclosure will hold all of the liquid contained in the tank and prevent its escape in case of fire. These tanks above ground are frequently struck by lightning. A safer method of storage is in underground tanks, and only such tanks should be permitted in the midst of populated districts. Yet in these cases special precautions should be taken in construction and maintenance to prevent corrosion and leakage, as the escape of these volatile inflammable liquids into sewers, wells, and cellars may lead to very serious disasters.

In the central part of Berlin, where real estate prices and electricity supply conditions are very similar to those which obtain in New York, there are quite a number of independent suction gas plants installed serving to deliver electric energy to individual blocks. It is seen that the average continuous fuel consumption per kilowatt hour is about 1% pounds of anthracite, corresponding to a price of a little more than half a cent. These results certainly encourage further efforts toward independence from public central stations. But they may even be improved upon by using lignite briquettes, with which a consumption of only 1.76 pounds per kilowatt hour is guaranteed by German manufacturers.

THE WORLD'S GREATEST GAMBLING HOUSE—
LLOYD'S.*

From a philosophical point of view, all insurance is gambling. On the risk hand is the underwriter betting that a certain thing will happen, on the other hand is the premium payer betting that it will not happen, or *vice versa*. As the difference between the amount of insurance and the premium widens the moral aspect naturally changes and the element of "protection" subdues all ethical misgivings, and the fact that in the case of a fire, a shipwreck, the loss of a limb, or life, a comparatively large amount of money is received for a comparatively small outlay, has come to be recognized as a modern social necessity.

The placing of insurance against the outcome of famous trials has been a common practice at Lloyd's since the days when the underwriters first met in Lloyd's Coffee House in Tower Street, London.

These risks are taken at the behest of gamblers always, the Lloyd's men deny, though as early as 1768 an article appeared in the London Chronicle condemning the coffee house as a "meeting-place for all manner of illicit gaming," and complaining that bets were made there "under the guise of insurance" on all the happenings of the day, from the outcome of elections to the trials of peers. It is said in defense of such risks as that placed on the Thaw case that thereby is furnished an insurance on the reputation of the lawyers engaged. The legal talent conducting a defense may by this means provide against the damage to prestige involved in an adverse verdict.

An example of the activity of the London underwriters in New York was the insurance taken out last summer by the managers of the Vanderbilt Cup race on Long Island. It is not revealed what the amount of the policy was or the premium paid, but the risk was against suits for damages arising out of accidents. It can scarcely be contended that Lloyd's centuries of experience gave the underwriters any data of value on the relative danger of the Vanderbilt course, and it may be supposed that the premium was high. It will be recalled that it was during this race that the first fatality among the spectators occurred, when Elliott F. Shepard's car struck a man who had stepped out on the course, killing him instantly.

The business of the Lloyd's agency as a corporation is marine insurance purely, but since the seventeenth century days, when the nucleus of the present organization was formed among the frequenters of the coffee house of Edward Lloyd in old Tower Street, the individual members of the group have been willing to take up any risk for a proper consideration. Then the safe return of a ship to port was a gamble at best, and insurance was little more than a gamester's business, but in these latter days the members of Lloyd's, who have reduced marine risks to a science as exact as life insurance, resent the likening of their trade to the bettors', and make claim with some reason that with the experience of more than two centuries it is possible to discount fate in every branch of human affairs with something like the scientific accuracy of the mortality table.

Of the thousands of odd insurances placed at Lloyd's, one of the longest standing is that held by a tradesman on the Strand, whose shop stands in the shadow of the Nelson monument. He has carried a policy for a generation against the possible damage to his premises should the monument fall. A certain group of underwriters make a specialty of insuring against the calamity of twins or triplets. This risk, it is claimed, has been reduced to a truly scientific basis, and the premium is arrived at only after a careful consideration of the family history of the insured and other data on which long experience has proved dependence can be placed.

Another of the legitimate sources of Lloyd's profits is established through the agency's information of the inside of European politics. During the South African war it was the general belief in the grain trade that the Czar would issue a ukase against the shipment of Russian wheat from the ports of the Black Sea. After a quiet investigation of the situation, Lloyd's established a premium rate against the contingency on which thousands of pounds' worth of insurance was taken out by grain merchants who looked for large trade in Russian breadstuffs with the army in the Transvaal. Lloyd's information that the ports would remain open proved correct, and the premiums were clear profit.

In recent years one of the largest losses sustained by the agency was through the postponement of the coronation ceremonies at the time of King Edward's illness. Thousands of stands had been erected along the route of the coronation procession, on which Lloyd's had sold insurance. The policies were against the prospective profits, and a rate of from 10 to 25 per cent had been made on the stands, according to positions, the idea of the underwriters being that only heavy rain would prevent their being filled to the utmost and the gross receipts reaching full expectations. The postponement of the ceremonies fell heavily on the Lloyd's underwriters, not only because of the losses on the stands, but out of the large number of policies sold to tradesmen on goods laid in against the expected holiday demand.

One item on which the loss mounted into thousands of pounds was the risk on their profits taken out by the dealers in the purple cloth, who had counted on selling millions of yards for decorations. The aniline dye used faded so quickly that the cheap cloths were worthless by the time the coronation finally took place. At the same time Lloyd's did a thriving business in

the sale of policies on the King's life, a means taken by tradesmen to insure themselves against the heavy curtailment of profits which would have resulted from a period of general mourning in London.

Another wholesale source of gain to the underwriters in recent years was during the smallpox scare in London in 1902. Policies were issued not only against individual infection, but against the losses to shopkeepers in case of quarantine. The panic was widespread and the policies were in great demand at high premiums, against which the losses were incon siderable.

War and the lives of crowned heads have always been the greatest source of the Lloyd's policies outside of the agency's legitimate business of marine insurance. It was during the period of almost continual disturbance in Europe between 1775 and 1815 that the Lloyd's brokers took their place as the leading underwriters of Europe. Never a cargo went to sea that was not insured against capture, and the success of the British navy in taking care of its own made profits great. In later times, though premiums have gone down with the diminished risk, a war cloud always means money in the pockets of the underwriters. During the Japanese-Russian conflict the shipments of contraband to both parties were inevitably insured at Lloyd's.

Lloyd's part in marine affairs is as wide as the seas. The rooms in the Royal Exchange are the news center of the fleets of the world. There are kept the records of every ship's master in the service of commerce, and the character of every hull fit to sail the seas. The beginnings of the intelligence service which has given the agency its fame and has reduced marine insurance to a science were in the gatherings of men of affairs in the coffee house of Edward Lloyd in Tower Street. The first mention of the little public house appears in an advertisement printed in the London Gazette in 1688, wherein Edward Lloyd offers a reward for the apprehension of a certain tall, dark, pockmarked individual who had lifted a watch or two. The proprietor himself, whose name is now known to the ends of the earth, wherever ships touch, was not concerned in the gambling business, which was then all that marine insurance could be called. His patrons gradually made the place a general exchange for news of the outside world, and in 1692, when the coffee house moved to Lombard Street, the proprietor undertook to gather the intelligence that came to his tables in the form of a printed gazette. In Lloyd's News, which he started about that time, was printed not only shipping news, but general information, and it was his dabbling with outside affairs that brought down the government censorship on his little sheet and stopped its issue after a brief existence.

Lloyd's List, which is the name still retained by the official organ of the agency, was founded in 1726, confining itself wholly to marine intelligence, and the paper continues to this day the oldest newspaper in England except the London Gazette. During the first century of its existence Lloyd's was conducted without any organization, but in 1774, after a succession of financial scandals inseparable from the eighteenth century fever for bubble speculation and insurance gambling, an association of insurance underwriters and brokers, calling itself the "New Lloyd's," took up its headquarters in the Royal Exchange, the predecessor of the present building, which is as much of a show place in financial London as the Bank of England or the Stock Exchange. The form of policy adopted by these associates continues unchanged to the present day but for the substitution of the more prosaic formula of "Be it Known That" for the pious opening phrase of the original form, "In the name of God, Amen."

The Lloyd's, after a long period of prosperous underwriting of war risks during the troubled years between 1775 and 1810, was investigated by Parliament and in 1811 was again reorganized. In 1871 the associates were incorporated for the threefold purpose of "carrying out marine insurance," "protecting the interests of its members," and "the collection and diffusion of intelligence and information with respect to shipping." At about the same time the "intelligence and information" branch of Lloyd's was separated from the insurance business in the formation of "Lloyd's Register of British and Foreign Shipping," whose rating is now the standard of all classification among the ships of the world's commerce.

Marine risks are the one class of insurance officially recognized at Lloyd's. The underwriting members of the body, who number about six hundred out of the total of 2,500 members, each deposit with trustees upon admission security to the value of \$25,000. This fund, amounting in all to about \$15,000,000, is the security corresponding to the capital and surplus of an insurance company. It applies, however, only to marine risks, and all of the strange policies issued by the underwriters are backed only by the credit and good faith of the men who underwrite them. Every coast that commerce touches is watched by an agent of Lloyd's, and all the marine insurance companies of the world depend upon the intelligence flashed to London from these outposts and on the information as to vessel and master supplied by the Lloyd's Register. It is from Lloyd's rating symbol for the best in hull and equipment that the familiar "A-1" is derived.

Besides the underwriting members, who are the bankers of the association, Lloyd's has two other classes of members, the brokers who get the business and the subscribers who want information only. At the door of the underwriters' room is the great register of shipping, in which the history of every registered hull afloat is set down. Not only the dry facts of its

condition and worth of hull, but its casualty history, for the luck of a vessel, as well as its material worth, enters into the calculations of the underwriters. Another book contains the story of every skipper in the commercial service, his birth and antecedents, his commands, and what has befallen them. The inexorable register hangs over the head of every master mariner, and he knows that the eye of Lloyd's is ever watching and that every mishap to his command will be surely recorded against his name in the book in London.

Carefully guarded from the public is the "Confidential Index," whose contents, too, are a large factor in the estimation of risks. Here the ship owners are tagged and billeted, their financial standing is duly rated, and their past dealings with the underwriters are kept track of. It is in this index, too, that the records of disgraced captains are kept, mercifully removed from the knowledge of all but the members of the agency.

When a broker has a policy to write he takes his memorandum to the underwriters' room, where they scrutinize it individually, and decide how much, if any, they will take of the risk. It is an individual bargain between the underwriter and the broker. Each underwriter is the representative of a group of the underwriting members, who, as has been said, are the bankers of Lloyd's. These men, after looking over the policy individually, will put down their initials for whatever amount they choose. The broker goes from one desk to another until the entire amount of the risk has been initialed on the slip. When the policy is made out the signatures of the underwriters are filled in, with the amounts taken, and the members of each banking group also attach their signatures to back up their underwriters. In this way the liability is taken personally by all concerned, and the profits also are divided individually. The security fund of the agency is used only to make good the failures of members, should such occur.

Among the underwriters those who make specialties of other forms of insurance are well known, and it is these men who take the odd risks, for which the agency is the world's market. The security for the payment of such policies is entirely a matter of good faith and credit, and Lloyd's as a body assumes no responsibility.

One of the famous attributes of Lloyd's is the ship's bell which hangs above the crier's rostrum. The news of every disaster at sea or the safe arrival in port of a ship long overdue is announced from this pulpit by the tall, red-cloaked crier of the Exchange. As he mounts the platform the bell is struck for silence, and when this bell, from the old ship-of-war "Lutine," is tolled as the crier announces the sinking of a ship or the decision of the board that a vessel long overdue must be lost, under English law all aboard become officially dead. The name of the ship and all that is known of the casualty is then put on record in a room which has been given the name of the "Chamber of Horrors." Hope is not abandoned, however, without taking into account all the contingencies which experience has taught the directors to look for. Unless there have been eyewitnesses to the sinking of the ship, Lloyd's waits until the owners as well as the committee agree that no hope is left; even then the rule requires that a bulletin praying information of the missing ship be posted for a week before the "Lutine's" bell is tolled in signal that losses will be settled.

ILLUMINATION AS AFFECTING THE EYE.*

By DR. WENDELL REBER.

THE most delicate photometer we have is the retina of the eye; it is the original of all photometers. We use the photometer sometimes in our work to ascertain various data. In certain people excessive tobacco smoking will reduce the acuteness of light perception. In others, lead workers, for instance, you will find very greatly reduced light perception, especially if their vocation is such that they inhale the lead dust. Painters are not so liable to reduced light perception as are workers in lead fixtures.

The retina, which is about as thick as a piece of tissue paper, is in itself a most marvelous chemical laboratory. It is the camera, dark room, and the whole thing in one, and the most wonderful chemistry is done there that is done in the world. It takes the picture, develops it, and presents it to your vision all in one operation.

The retina is backed up with a pigment layer, to do away with radiation, and if people work under too high a light stimulus, a certain amount of the protection got from the pigment is used up. These people usually begin to show an intolerance of ordinary light. Of course, to-day, when you begin to talk about ordinary light, the question arises, "What is ordinary light?"

There is a greater temptation to abuse the human eye to-day than there ever was. Nowadays light can be instantly produced in any hour of the twenty-four. Not so in the days of candles, when people went to bed early. We turn night into day in almost every possible way, and in almost every way we use our eyes in a manner that our forefathers never did. Everyone does now about three times the work in 16 or 17 hours that people did 100 years ago, and the consequence is many people are wearing glasses.

Of course, the matter of lighting public buildings, schools, etc., is one of the big present-day problems of this country. Twenty-five years ago the Germans were prompted to go into this matter because their generation was rapidly becoming near-sighted. Japan is

* A discussion before the Philadelphia section of the Illuminating Engineering Society.

pushing them hard for that honor. With the Germans the cause is found in three things: Abominable type, insufficient illumination, and poor hygienic conditions, all of which they are making terrific struggles to overcome. They went at their schools and applied their principles in the right way, and every German scientific publication of to-day is published in the Gothic type, and they are trying very hard to use it in their textbooks. The average person who studies Greek or German is in danger of becoming near-sighted.

lowing one another at certain intervals in the path made by the first discharge. The writer was unaware at the time that others had experimented in the same line and had published their results.

The camera was moved by hand, being swung from right to left and back again, each swing lasting about one second and covering an angle of about 60 deg., which was also the angle of the lens. The apparatus employed was an ordinary magazine plate camera, which for all ordinary purposes is the most convenient

0.5 millimeter apart, and from there for a distance of 10 millimeters are a series of discharges close together, forming a broad band. The dark space which divides this flash is a cloud through which the discharge is passing. Another interesting fact about this flash is that the path of it is spiral shaped, the motion is from right to left, or opposite to the motion of the hands of a clock, looking downward from the cloud. Fig. 3 was obtained October 1, 1903. We have here a flash composed, first, of two bright discharges close to-

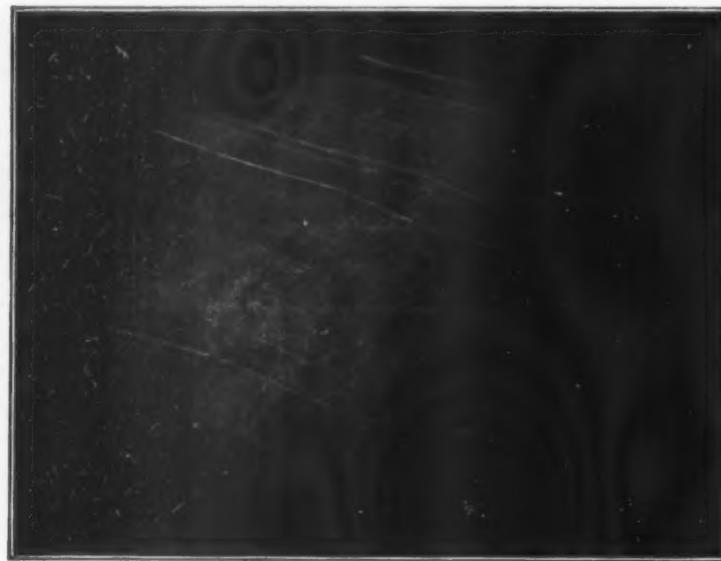


FIG. 1.—LIGHTNING FLASH TAKEN JULY 17, 1902.



FIG. 3.—LIGHTNING FLASH TAKEN OCTOBER 1, 1903.

It is evident that we are developing a large proportion of near-sighted young people in our schools, and the ratio of those who are far-sighted is much lower than it ought to be. Every schoolhouse ought to be constructed to get the greatest amount of light consistent with the safety of the building. For the minimum amount of light there should be not more than five square feet of floor space for each square foot of glass. The German government intends creating a commission of architects or engineers to decide how the lighting of schools shall be carried out, and this question will receive attention as schools are built.

PHOTOGRAPHING LIGHTNING WITH A MOVING CAMERA.*

By ALEX LARSEN.

LIGHTNING, with its accompaniment of thunder, has always exerted a fascinating influence on the thinking mind. It is not strange that a people living in an age when the laws of nature were less perfectly understood should have associated this beautiful and awe-inspiring natural phenomenon with the powers and attributes of their gods.

The ancient Norsemen recognized in the rumbling of the thunder the approach of Thor, their most powerful god, in his heavenly chariot, drawn by his two he goats; and in the lightning flash they saw the path cleaved through the air by the never-falling hammer "Mjolner," wielded by the mighty arm of Thor when battling with the enemies of the gods, the hammer always returning to his hand. The myth is beautiful, and it would seem as if its authors had noticed the peculiar flickering of most lightning flashes and associated it with the forward and return movement of the hammer.

The principal object of this paper is to place before

on account of the rapidity with which the plates can be changed, this being of great importance, because, as a rule, the time most favorable for obtaining good pictures is very short, seldom lasting longer than from ten to fifteen minutes.

Several more pictures were obtained in 1903. The three most interesting ones up to that year are shown in Figs. 1, 2, and 3. Fig. 1 shows a flash obtained on July 17, 1902. The discharge took place between two clouds. It will be noticed that it is composed of a number of separate discharges (or rushes) and bands; as many as thirty-four can be counted on the negative. As the flash covers about half of the plate, and as the approximate speed of the camera was about one second to cover the plate, or 60 deg., it follows that the approximate duration of this flash was about half a second. Fig. 2 shows a flash obtained on July 11, 1903. This flash is interesting for several reasons. It is composed of fourteen separate discharges, the

gather, then there appears to be an interval of about a fourth of a second, which in all probability was filled in with a number of fainter oscillations (the lines running across seem to indicate that), and at the conclusion of the flash are four fairly bright rushes.

In the summer of 1904 copies of some of the photographs were sent to the Smithsonian Institution for examination, and through the suggestions and assistance of the experts of that Institution a new method of moving the camera was devised.

A spring-motor movement (of the kind used to operate revolving stands for exhibiting goods in show windows) was procured and mounted inside a table specially constructed for the purpose, and a stand for supporting the cameras was fitted to the central shaft.

As the speed of the motor was too slow, the fly-vane shaft was removed and the vane moved to the next shaft, which was lengthened so as to extend under the table. Thus arranged the fly-vane could be made to



FIG. 2.—LIGHTNING FLASH TAKEN JULY 11, 1903.

its readers certain facts to account for this flickering of lightning flashes.

In the latter part of the summer of 1901, while taking some ordinary pictures of lightning, the idea occurred to the writer while noticing this flickering that if the camera be moved in a circle at right angle to the flash the picture ought to show a widening of the flash, if it was composed of separate parts, and thereby also determine its duration. The attempt to do this was made that year, but without success. It was repeated again in 1902, and on July 17 several successful exposures were made which clearly showed that most flashes are composed of several discharges fol-

* The study of lightning flashes herewith presented was aided by a grant from the Hodgkin Fund of the Smithsonian Institution. The paper is re-published from the annual report of the Smithsonian Institution.

first one being the brightest, and having side branches pointing downward, proving that the first discharge passed from the cloud to the earth and that the resistance which it had to overcome must have been excessive (the side branches prove that). At a distance of 3 millimeters from the first rush is another discharge following the same path, but without side branches (what appear as such are really branches from the first rush). At a distance of 12.5 millimeters from the last discharge will be seen two rushes

revolve in a liquid placed in a vessel under the table, thereby preventing much of the vibration and getting a more uniform speed. Fig. 4 shows the arrangement of the apparatus. The table top is removed in order to show how the motor movement is placed; the fly vane is seen under the table. The stand is usually revolved at a speed of one revolution in ten seconds, which the writer has found to be the most suitable for ordinary purposes. The reason for employing a motor movement with a uniform speed to move the camera

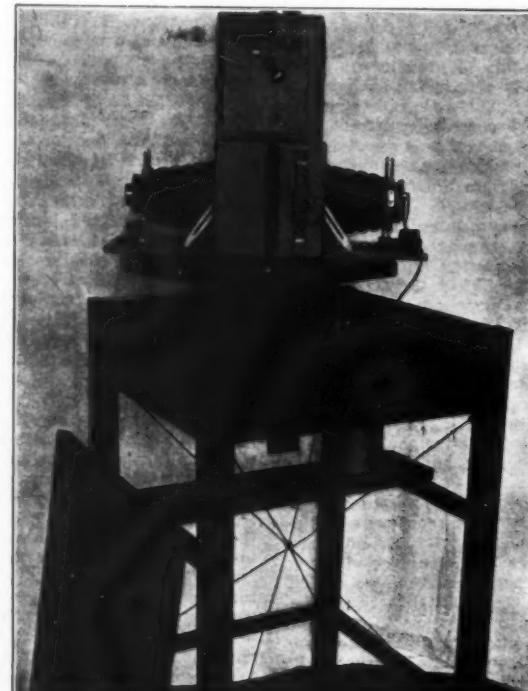


FIG. 4.—MOVING CAMERA APPARATUS FOR TAKING LIGHTNING FLASHES.

is to ascertain the exact duration of a flash or the intervals between the rushes.

If the angle of the lens and the speed of the camera be known, it is a simple matter of measurement to

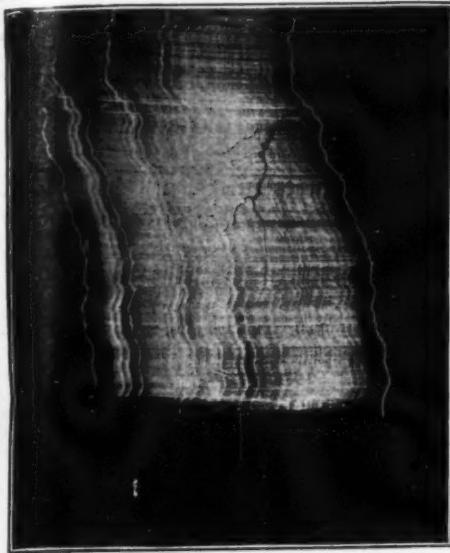


FIG. 5.—LIGHTNING FLASH TAKEN SEPTEMBER 1, 1905—9 P. M.

Two reproductions, to show separate rushes and black discharge.

ascertain the duration of a flash. The formula employed is as follows:

Call the angle of the lens (in degrees) = A°

Time for one rotation of stand (in seconds) = T

Width of plate (in millimeters) = W

Width of flash measured on plate (in mm.) = N

$$\frac{A^\circ}{360} \times T$$

Then time for flash (in seconds) = $\frac{A^\circ}{360} \times N$.

The measurements should be taken from the middle of the plate, owing to the distortion of the lens.

A number of photographs have been taken by this method, and about nine out of ten show the multiplicity of a flash. The average number of rushes for each flash is about five or six, and the time varies from an almost instantaneous value up to about half a second for a complete discharge.

The most interesting discharge obtained is shown in Fig. 5. It was taken September 1, 1905, at 9 P. M. The storm during which this flash was photographed

was obtained when the storm was most severe and while it was raining very hard.

This flash is composed of forty separate discharges, made up of one band, which in all probability is composed of a number of separate rushes or oscillations very close together and one black discharge. It is this dark discharge which makes this flash interesting, and the photograph shows it running parallel and on both sides of the first bright rush, extending 0.6 millimeter on one side and 0.1 millimeter on the other, the boundary line on the latter side not being very marked. From this black discharge issue several side branches on both sides, a large one spreading out over the other rushes quite prominently. These side branches all pointing downward indicate that the black flash was a downward stroke, and they also tend to prove that it must have had a good deal of resistance to overcome. It must have cleared the way for the first bright discharge, which in all probability proceeded from the ground upward. The difference in width of the bright flash, measured at its lower and upper part, would confirm this opinion, being for the lower part 0.38 millimeter and for the upper part 0.22 millimeter.

An interesting question here presents itself. Have we here two separate discharges with different rates of oscillation traveling the same path? Can such a condition be possible? To the writer's mind the most plausible explanation would be that the two discharges occupied two separate paths, one inside of the other, one discharge forming, so to speak, a tube through which the other passed.

It may also be claimed that the bright flash is probably part of the dark discharge for some reason rendered more luminous. This explanation may be the

by the other rushes following. The effect of halation and solarization was also considered, but rejected. There was thus but one way to account for the phenomenon, namely, that the flash must have given out light of a wave length much shorter than the wave lengths of visible light and with a power sufficient to



FIG. 7.—SPECTRUM PHOTOGRAPH OF LIGHTNING FLASH, SEPTEMBER 1, 1905.

render the portion of the plate struck by it non-sensitive to ordinary light. Such a flash would appear black on a partially illuminated background or be invisible.

Dark flashes have been observed by the writer on

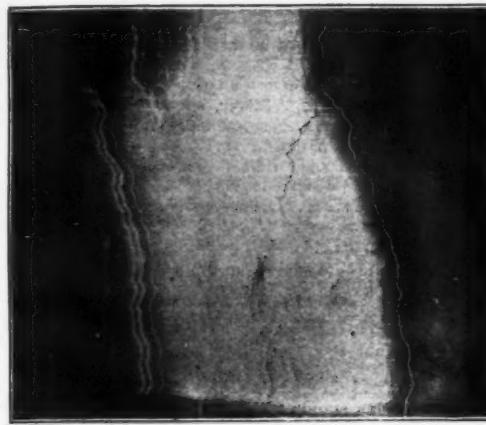


FIG. 6.—SPECTRUM PHOTOGRAPH OF LIGHTNING FLASH, JUNE 18, 1905.

began about 7 P. M., with the wind northeast, which is something very unusual for Chicago. The wind gradually changed to north and northwest. The temperature during the storm was about 24 deg. C., and the barometer varied between 29.89 and 29.92. The flash

true one, although it appears as if the bright flash is entirely separate. The measurements of the width of the upper and lower parts of both flashes confirm this opinion, the difference in width of the bright flash being 40 per cent and for the dark discharge only 20 per cent. Authorities vary in their opinions as to the probable cause of these dark flashes. It has been suggested by some that there really are no black discharges, but what appear as such are excessively bright flashes causing a reversal of the image on the plate. This explanation may be the true one if we understand the word "brightness" to mean increased actinic power of the light. In the black flash represented this chemical effect must have been extremely high, owing to the fact that the smallest hair-like extremities of the side branches are well reproduced on the picture as black, in comparison with the broader and to all appearance more powerful discharges which followed after.

It was at first thought probable that we had to deal with an interference phenomenon, but that idea was discarded. Then it was suggested that the black discharge was probably due to slow oscillations (the width of it would tend to confirm this opinion), and

several occasions and only when raining very hard. They appear to the eye the same as the accidental image produced after looking at a bright flash. Such an image may be retained in the eye for quite a while after, but cannot easily be confounded with a real flash.

Two other pictures of dark discharges have been ob-

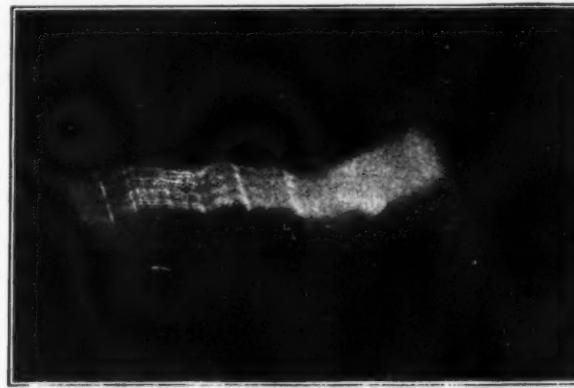


FIG. 8.—SPECTRUM PHOTOGRAPH OF SPARK FROM STATIC MACHINE.

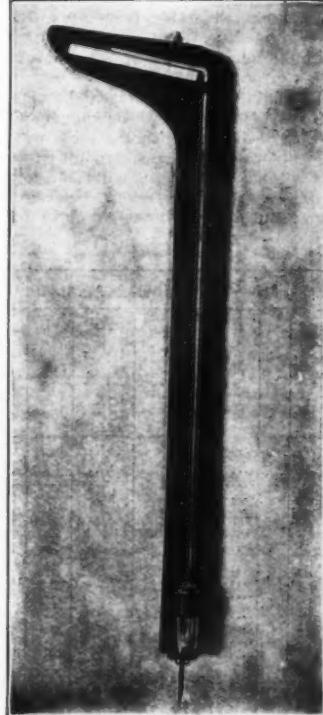


FIG. 9.—LARSEN BAROMETER.

tained with the moving camera, but are not so prominent; they likewise show the first rush as black, but without a bright core and with no side branches; one is of a horizontal and the other a vertical flash.

Below is a table of the measurements of this flash.

The angle of the lens was 60 deg. Time of rotation of camera, 1 revolution in 10 seconds. Width of plate, 127 millimeters. The width of the whole flash, 48 millimeters. Time for the whole flash, 0.624 second. The average distance between the rushes, 1.2 millimeters. Average time for each rush, 0.0156 second. The plate used was a "Standard" ordinary plate. The contrast of the picture has been increased by means of a double-contact print with lantern-slide plates. The developer was "rodinal." Time for developing, five minutes.

LIGHTNING FLASH (FIG. 5).

Designation.	Distance, Min.	Time, Second.	Designation.	Distance, Min.	Time, Second.
Width of black rush.			From 24th to 25th rush	0 70.0001	
From 1st to 2d rush.	1 00 0120		From 25th to 26th rush	0 70.0001	
From 2d to 3d rush.	2 60 0280		From 26th to 27th rush	0 80 0104	
From 3d to 4th rush.	1 20 0200		From 27th to 28th rush	1 00 0130	
From 4th to 5th rush.	1 00 0240		From 28th to 29th rush	0 50 0065	
From 5th to 6th rush.	1 00 0180		Width of 29th rush	0 40 002	
From 6th to 7th rush.	0 70 0091		From 29th to 30th rush	0 70 0001	
From 7th to 8th rush.	0 90 0117		Width of 30th rush	0 40 003	
From 8th to 9th ru-h.	0 90 0117		From 30th to 31st rush	1 30 0106	
From 9th to 10th rush.	1 70 0200		Width of 31st. sh	0 80 0104	
From 10th to 11th rush.	1 70 0200		From 31st to 32nd rush	0 50 0079	
From 11th to 12th rush.	0 60 0078		Width of 32d. m.	0 60 0029	
From 12th to 13th rush.	0 90 0117		Width of 33d. r. sh.	0 60 0029	
From 13th to 14th rush.	1 10 0120		Width of 33d. r. sh.	0 60 0029	
From 14th to 15th rush.	0 70 0091		Width of 34th rush	0 20 0006	
From 15th to 16th rush.	0 50 0065		From 34th to 35th rush	0 50 0065	
From 16th to 17th rush.	0 60 0078		Width of band	0 40 0020	
From 17th to 18th r. sh.	0 50 0065		From 35th to 36th rush	1 60 0208	
From 18th to 19th r. sh.	1 30 0169		From 36th to 37th r. sh.	1 60 0198	
Width of 19th rush...	0 60 0078		Width of 37th rush	0 90 0117	
From 19th to 20th rush.	1 40 0182		From 37th to 38th rush	0 40 0062	
From 20th to 21st rush.	0 70 0091		Width of 38th rush	0 60 0078	
From 21st to 22d rush.	1 40 0182		From 38th to 39th rush	0 40 0062	
From 22d to 23d rush.	0 20 0090		Width of 39th rush	0 40 0062	
Width of 23d rush	0 40 0063		From 39th to 40th ru-h	3 60 0498	
Width of 24th rush...	0 40 0062		Total	48 00 6240	

In the summer of 1905 a new departure was undertaken by the writer at the suggestion of the secretary of the Smithsonian Institution, the object being to obtain spectrum photographs of lightning.

Spectroscopic examinations of lightning have been made by many, but most of these observations have been visual, which at their best can only be rough approximations of the number of lines and their relative positions. As far as the writer knows, only one institution in the country—the Harvard College Observatory—had undertaken any work in photographing the spectrum of lightning.

A crude apparatus was constructed, consisting of a camera with a 35-millimeter prism fitted in front of the lens, no slit being used, as a lightning flash is a relatively narrow streak of light yielding a practically parallel beam. By means of this arrangement a few photographs have been obtained, two of which are reproduced in Figs. 6 and 7. A spectrum photograph of a spark from a static machine, for comparison, is shown in Fig. 8.

The spectrum shown in Fig. 6 is from a vertical flash, the picture of which was obtained June 18, 1905. It was about $1\frac{1}{2}$ miles distant and was taken at the end of a storm of local character. The spectrum of this flash resembles that from the static machine in most of its details.

Fig. 7 shows the spectrum of one of those horizontal meandering flashes often seen at the conclusion of a storm of long duration. It was obtained September 1, 1905. It differs considerably from Figs. 6 and 8, several lines being absent. The first line of this spectrum is probably the same as the eighth line of the spark spectrum.

No definite opinion can at present be offered by the writer as to the meaning of these changes of the lines in the spectra of different flashes; more material must be obtained before a positive statement can be made.

Below is a table of measurements of the three spectra and their probable relations. Several measurements have been taken, and the averages are here presented.

Spark (Fig. 8).		Lightning (Fig. 6).		Lightning (Fig. 7).	
Line.	Intensity.	Line.	Intensity.	Line.	Intensity.
Width, Min.	Distance, H.yd.	Width, Min.	Distance, H.yd.	Width, Min.	Distance, H.yd.
2 0 0.1	II β	4.861	1 (?)	II β	4.861
1 0 0.05	0.87				
3 0 0.1	0.43				
4 0 0.05	0.62				
5 0 0.2	0.5				
6 0 0.2	0.25				
7 0 0.12	0.3				
8 0 0.4	0.87				
9 0 0.6	0.05				
10 0 0.05	0.40				
11 0 0.05	0.40				
12 0 0.4	0.85				
13 0 0.25	0.25				
14 0 0.25	0.5				
15 0 0.3	0.5				
16 0 0.25	0.55				
17 0 0.2	0.2				
18 0 0.4	0.9				
19 0 0.6	1.3				
20 0 0.8	1.6				
.....	10 4 1.2	1.5
* Band.	Double.			11 2 (?)	3.

It may not be out of place here to give a few brief hints as to the best method for obtaining lightning photographs, for the benefit of the large number of amateur photographers scattered over the world. Thunder storms are nearly always cyclonic in their

character, their diameter varying. When they extend over large areas it will usually be found that most of the vertical flashes are at the circumference of the circle through which the storm is passing. In the central part of a storm the flashes are usually horizontal, or passing between two strata of clouds, therefore the best time for obtaining photographs is either at the beginning or the end of a storm. At the beginning the wind is usually very strong, hindering the work, so that it is generally best to wait until the front of the storm has just passed overhead and then to expose the camera from a window or other suitable place facing a direction opposite to that of the wind. In this way the camera as well as the person will be protected from the wind and rain. This rule holds good in most cases, although there are many exceptions, especially when the storm is local in character and of small extent. A person must be on the lookout at all times and note the direction in which most of the downward strokes appear and direct the camera toward them.

It is useless to expose plates when there is nothing but sheet lightning, for it will only result in spoiling them. Oftentimes there is a mixture of sheet lightning and a few scattered ground strokes at uncertain points. When that be the case, the chances for obtaining pictures are slight, the sheet lightning soon fogging the plates, the time for fogging in such cases being from five to ten minutes, depending on the frequency of the reflections. The best rule to follow is to wait until a favorable opportunity presents itself, when the flashes are about half a mile distant, then act quickly, have plenty of plates ready to insert in place of the exposed ones, and trust to luck. The best way of holding the camera when swung by hand is to place it close to the body, tilting it somewhat upward, so as to get as much as possible of the sky in the picture, and swinging the body from side to side. The time and angle of the swing can be regulated with a little practice so as to be fairly accurate, say one second to the swing, although the writer has found by experience that when a sudden flash appears in front of the camera the evenness of the swing will be somewhat disturbed, particularly if the flash is close to the observer, unless the person be in possession of unusually strong nerves. When pictures of horizontal flashes are desired the camera must naturally have an up and down swing. These flashes are usually less intense and the pictures of them sometimes require a very long time to develop. The developer preferred by the writer is "rodinal," being convenient and clean, although any good developer will do, particularly such contrast developers as "glynin" or "hydrochinon."

Different kinds of plates have been tried, but the writer has no special preference for any one of the standard plates. The orthochromatic plates do not seem to give better results than the ordinary ones. Films give trouble in developing, because each exposure must be developed separately.

Fig. 9 shows the barometer devised by the writer, which he has found very useful in the study of the variations of the atmospheric pressure preceding and during storms. The instrument recommends itself on account of the simplicity of its construction, its accuracy, and the ease with which the readings can be made, less than one two-hundredth part of an inch being easily read off without the aid of a vernier. The instrument shown in the illustration consists of a glass tube, one-fourth inch inside diameter, 38 inches long, bent to an angle of 100 deg. at a distance of $8\frac{1}{2}$ inches from the closed end, filled with mercury, and mounted with the open end dipping into a reservoir, which in this case is 1 inch in diameter. The open end can also be bent up to form a siphon barometer. The scale is placed along the upper slanting part of the tube. A pointer is fastened to the lower part of the instrument, the use of which is to indicate when it is in an exact vertical position, a mark on the wall indicating this position. The surface tension of the mercury is overcome by gently swinging the instrument and returning it to its vertical position. The calibration may be done by comparison with a standard instrument or by actual measurements. The bend of the tube may be made at a different angle, but should not be much less than 100 deg. owing to the surface tension of the mercury. With this angle the instrument will magnify about six times, which has been found by the writer to be sufficient for ordinary use. The range of the instrument described is about two inches, and if a greater range is desired the slanting portion of the tube may be made longer or a different angle of the bend be substituted, although the proportions given have been found by experience to give the best satisfaction. A tube with a small internal diameter does not give good satisfaction owing to the surface tension being greater.

A NEW GALVANOPLASTIC PROCESS.

By A. BREYDELL.

In the ordinary galvanoplastic process the object which is to be electroplated is connected with the negative pole of a battery or dynamo and completely immersed in a solution of the plating metal, together with an electrode of this metal which is connected with the positive pole of the source of electricity. Hence it is necessary to use a bath large enough to contain and cover the whole of the object, a condition which becomes impracticable when the object is very large. Furthermore, in order to apply different metals to different parts of the same object it is necessary to use successive baths, in each of which certain parts are protected by an insulating varnish.

R. Goldschmidt has invented a process which avoids

some of the inconveniences, especially in cases where only a thin coating is required. It is not advocated as a substitute for the processes in current use but as a supplementary method, applicable to many cases occurring in practice. Besides, it is so simple that it enables any person to produce a great variety of galvanoplastic effects with a very modest equipment and the ordinary lighting circuit of 110 volts.

In Goldschmidt's process the bath is replaced by the small quantity of the electrolytic solution that can be carried by an ordinary paint brush. The brush, connected with the positive pole of the source of electricity by a wire of the plating metal which is wound tightly around the base of the bristles, thus becomes at once the plating bath and the anode. The object to be plated being connected with the negative pole it is merely necessary to pass the brush over it to obtain instantly, if the surface has been thoroughly cleaned, a regular and firmly adhering deposit.

The thickness of the deposit depends, of course, on the duration of the process and the number of times the brush is applied. The writer has obtained the best results by inserting the object, the brush and five or six incandescent electric lamps in series in a 110-volt circuit. This arrangement should give a current of about 1/10 ampere.

The new process promises to be very useful in both laboratory and commercial work. It provides a simple and expeditious method of protecting from atmospheric influences objects of any size which are either made of metal or have a conducting surface, and it enables the jeweler to produce polychrome effects easily and cheaply. Although the deposit is very thin it adheres perfectly and, if protected by a coat of lacquer, it is sufficient for most purposes.

The following solutions, which are often employed for ordinary plating baths, are found to give the best results:

	Parts by Weight.
Silver.	
Silver nitrate	20.0
Potassium cyanide	30.0
Ammonia (90 per cent)	0.4
Potassium formate	2.0
Water	1,000
Gold.	
Gold chloride	6
Potassium cyanide	13
Ammonia (90 per cent)	2
Water	1,000
Dissolve and then add	
Potassium formate	2
Copper.	
Copper sulphate	180
Concentrated sulphuric acid	60
Water	1,000
Alcohol (90 per cent)	10
Nickel.	
Nickel sulphate	60
Sodium sulphate	20
Sodium citrate	20
Water	1,000

For nickel plating a low voltage, 2 to 4 volts, gives the best results.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Cosmos.

THE THEORY OF MOUNTAIN MAKING.*

The Geological Survey of Pennsylvania made known the folded structure—the alternate anticlines and synclines—of the Appalachians. The beautiful sections of these folded strata, in the Atlas of that survey, reveal the thoroughness with which the structure of the mountains was investigated by Henry D. Rogers; and can be studied with delight to-day. In spite of the fantastic nomenclature, which the student has to translate into the familiar language of the New York Survey. In those sections it appears that, in general, each fold is unsymmetrical, the dip on the northwest side being steeper than that on the southeast, if, indeed, the dip on the northwest side is not carried beyond the perpendicular and reversed. While in each fold, as a rule, the dip is steeper on the northwest side than on the southeast, if we compare the successive folds, we find the dips growing more gentle as we go from southeast to northwest. The nearly vertical or overturned dips of the folds on the eastern border pass by a gradual transition into gentle undulations on the western border of the Appalachian zone.

While the stratigraphy was worked out so beautifully in the first Geological Survey of Pennsylvania, the dynamic conception derived from it was crude indeed. The conclusions of the author are summed up in the following sentences: "The wave-like structure of undulated belts of the earth's crust is attributed to an actual pulsation in the fluid matter beneath the crust, propagated in the manner of great waves of translation from enormous ruptures occasioned by the tension of elastic matter. The forms of the waves, the close plication of the strata, and the permanent bracing of the flexures, are ascribed to the combination of an undulating and a tangential movement, accompanied by an injection of igneous veins and dykes into the rents occasioned by the bendings. This oscillation of the crust, producing an actual floating forward of the rocky part, has been, it is conceived, of the nature of that pulsation which attends all great earthquakes at the present day." The wave-like form of the Appalachian anticlines and synclines is a beautiful generalization of accurate and conscientious ob-

*Abstract of a paper read by William North Rice before the American Association for the Advancement of Science.

servation; but the dynamic theory suggested for its explanation needs to-day no other refutation than its simple statement.

But, however completely the Pennsylvania geologists failed to construct a satisfactory theory of mountain-making, their observations of Appalachian structure were of immense value in their destructive effect upon some of the notions of mountain-making prevalent at the time. In the text-books in the early part of the nineteenth century, a diagram often appeared representing a transverse section of an ideal mountain range. A vertical wall of crystalline rock forms the center and the crest of the range. Against this wall, on each side, the oldest strata lean in a nearly vertical position; farther from the center, strata of less antiquity lean with more gentle dips against the steeper and older strata; and finally, on the flanks of the mountain range, still newer strata rest nearly horizontally. The diagram represents a dislocation of the strata by repeated vertical upthrusts of the crystalline core. Of course, it was seen at once that there was nothing common to these ideal sections and the real sections of the Appalachians revealed by the Pennsylvania Survey. The billowy form of the Appalachian folds meant something, and something very different from the prevalent conception of mountain ranges.

The true interpretation of the Appalachian waves is probably to be found in the contractional theory of mountain elevation, of which Dana was the leading expounder. The views of Le Conte on the subject of mountain making were in most respects similar to those of Dana. But, while Le Conte's discussions were of great value, the priority in the general development of the theory belongs to Dana. "To the North American geologists," says Von Zittel, "undoubtedly belongs the credit of founding the theory of horizontally acting forces and rock-folding upon an ample basis of observation."

That the main cause of mountain elevation is tangential pressure in the crust resulting from internal contraction, is now generally acknowledged, though there may be doubt whether the main cause of contraction is the cooling of the earth from an incandescent condition, as assumed in the commonly accepted form of the nebular theory, or the gravitational adjustment of an incoherent mass of meteors, as assumed in the more recent planetesimal hypothesis of Chamberlin and Moulton.

The idea of the contractional origin of mountains was not, indeed, original with Dana. There was a glimmer of the idea in the writings of Leibnitz, and Constant Prévost developed the idea into a definite scientific theory; but the elaboration of the theory into its present form we owe chiefly to Dana. His discussion of the subject began in the *Journal of Science*, in 1847. In later years he returned to the subject again and again; and the theory, as shaped by his maturest thought, appears in the last edition of the "Manual." In his earlier writings his views of the origin of continents and mountains were developed on the assumption of a liquid globe. In later years he abandoned that view, and adjusted his theories to the more probable doctrine of a globe substantially solid.

The conception of the subsidence of the suboceanic crust, which led Dana to his views of the permanence of continent and ocean, is an important element in his theory of mountain making. In the contraction of the earth's interior, the suboceanic crust necessarily flattens in its subsidence, so that its section continually approaches the chord of the arc, thus exerting a tangential thrust toward the continental areas. The rather abrupt change in the radius of curvature in passing from the oceanic to the continental areas makes the continental borders lines of weakness which determine in general the location of the great mountain wrinkles. In the two continents of North and South America, with their mountain borders on the east and west and their vast interior plains, Dana found exemplified the typical continent. Their isolated situation seemed to allow a more typical development than was possible in the Old World, where continents are massed together; as the laws of crystalline form can exhibit themselves in perfection only where a single crystal in a solution or magma is allowed to grow without interference of other growing crystals.

According to the views of Dana and Le Conte, mountain ranges have been only exceptionally developed by geanticlinal uplifts of the earth's crust. A mountain range, in general, has its birth in a geosyncline—a downward folding of the crust, forming a trough, in which sedimentation goes on *pari passu* with the subsidence. At length, after long ages of subsidence and sedimentation, the strata in the trough are crushed together into alternate anticlines and synclines, or one part is forced over another in great thrust faults, while slaty cleavage and more decided metamorphism may be produced. The mountain range thus produced Dana called a "synclinorium," while he suggested the name "anticlinorium" for a mountain range formed by a permanent geanticlinal elevation. Apparently the actual history of most mountain ranges is complex. The Appalachian range, for instance, was formed as a synclinorium at the close of the Paleozoic, degraded nearly to base-level in Mesozoic time, and again elevated by a broad geanticlinal movement early in Cenozoic time. It represents, therefore, in its complex history, Dana's two types of the synclinorium and the anticlinorium.

There are unquestionably weak points in the theory of mountain making as developed by Dana and Le Conte; and, in our ignorance of the conditions in the interior of the earth, and of the forces there in ac-

tion, it ill becomes us to be dogmatic; but the contractional theory seems worthy of provisional acceptance as the most plausible explanation of orogenic movements yet suggested.

ENGINEERING NOTES.

The first twin turbine steamer to be launched in the United States was sent into the water at the yards of the Fore River Shipbuilding Company, at Quincy, Mass., on September 19, 1906. She was built for the Southern Pacific Company, and will run between New York and New Orleans. She is named the "Creole," is 440 feet long, 53 feet deep, 10,000 tons, and will have a speed of 16 nautical miles per hour.

One of Nature's most wonderful and unique products is asbestos, a material which, in spite of its extensive use, is comparatively unknown to the general public. Prior to 1850, it was looked upon principally as a curiosity, although Charlemagne (Roman Emperor from 800 to 814 A. D.) is said to have had a table cloth made of asbestos, which he cleaned by throwing it into fire. There are two varieties of commercial asbestos, known as amphibole and chrysotile. The former is used only to a comparatively small extent, as the fibers are short and without tensile strength and are, therefore, not suitable for manufacturing many of the asbestos products. Amphibole is used to some extent in cement, but is not well adapted even for that purpose. Chrysotile, on the other hand, has a strong and silky fiber, which adapts it for such materials as asbestos fabrics, household utensils, theater curtains, clothing for firemen, etc. In Germany, asbestos is known as *Steinfasch* (stone flax) and the miners of Quebec give it quite an expressive name—*pierre coton* (cotton stone). Asbestos is mined in open pits, similar to stone quarries, and although it is found in all parts of the world, the mines in Quebec, Canada, are the most famous, yielding about 85 per cent of the world's supply of chrysotile. In 1879 the output of the Quebec mines was 300 tons, which has steadily increased year by year to 50,000 tons in 1905.—Mining World.

Experiments were made at the National Physical Laboratory on the elastic limits of specimens which had been subjected to a considerable number of reversals of direct stress, which showed an agreement of the range between the elastic limits as determined by a sensitive extensometer and the range of stress for which fracture will just not occur after indefinite repetitions of the stresses. Referring to these results, Prof. Unwin quoted from a recent article by Prof. A. Martens as follows: "For the case of alternating tension and compression sufficient knowledge is still lacking, as the phenomena which may be expected to take place under these conditions cannot be identified in Bauschinger's laws," and then adds that Bauschinger had not quite succeeded in getting the above results. It is proposed, therefore, to add to these preliminary results and further to examine specimens of iron and steel with the object of arriving at a definite conclusion. By subjecting these materials to a number of reversals of stress of a range less than the limiting range and examining by means of an extensometer, it is hoped that the change due to an increase in the range of stress can be followed from the primitive condition to the limiting condition corresponding to the limiting range of stress. All the preliminary experiments bearing on the point indicate a complete absence of elastic range for repetition of all stresses of greater magnitude.

Under processes recently patented a remarkable step in advance in the manufacture of stone-like substances has been achieved. The inventor has succeeded in what is little short of a reconstruction of many well-known qualities of building stone. By a slight modification of his processes he produces all kinds of marble, and one of his chief successes has been in the manufacture of lithographic stone, which has been pronounced by experts to surpass some of the best samples of the natural product. In using slag for the production of an artificial stone, it is broken up in a stone breaker with crushing jaws of the usual type, and is ground to powder in a disintegrator. The powdered slag is then mixed with quicklime, seven parts of slag being used to one part of lime, and the substances are thoroughly amalgamated in a revolving mixer and subsequently "pugged" with an excess of water to form a pasty mass of creamy consistency. This is subjected to very heavy pressure in metal molds, squeezing out nearly all the water, and formed into blocks of the consistency of chalk or stiff marl. After the blocks are quite dry they are placed in stout iron cylinders from which the air is exhausted, and when a complete vacuum is obtained carbonic acid gas is introduced and is allowed to permeate the stone for a period of three days. By this treatment the hydrate of lime becomes recarbonated and serves to bind the mass into a substance as hard as rock. If for the slag a basis of marble, limestone, or dolomite is substituted, it becomes possible to prepare a mixture, as heretofore described, in which from three-fourths to seven-eighths consists of calcium hydrate, or a mixture of calcium and magnesium hydrates, obtained by calcining the stone. These blocks can readily be impregnated with the carbonic acid gas, by which means the lime and magnesium are converted into carbonates and serve to consolidate the mass and turn the whole substance into stone. In the case of marbles, or when making lithographic stone, a certain amount of coloring matter can be added to the paste. The finished stone or marble is capable of a high polish, and is said to possess all the weather-resisting properties of the natural rock used in its production.—London Times.

SCIENCE NOTES.

The Röntgen Society has appointed a committee, with Prof. C. V. Boys, F.R.S., as chairman, to study the subject of radio-activity, with the view of obtaining, if possible, a standard of radio-activity suitable for those whose work includes the investigation or use of radio-active substances and X-rays. The need for a means of testing the activity of Röntgen bulbs is felt especially keenly by those who use them in connection with therapeutics and surgery. A paper on the subject by Lord Blythswood and Mr. W. A. Scoble is printed in the February Journal of the Röntgen Society.

Mr. Malcolm MacLaren, in the Geological Magazine for December, 1906, discusses "The Origin of Certain Laterites." The peculiar features about laterites which require explanation are their restriction geographically and in altitude, their general superficial occurrence and their internal structure—porous, vesicular, pisolithic, or concretionary, their composition as regards the aluminous, ferruginous, or manganiferous hydrates, the general presence of titanium dioxide and the absence of kaolin or silica. The results of the author's field work, supplemented by microscopic examination and chemical analyses, leads to the conclusion that "laterite must be regarded not as the direct product of the decomposition of a rock *in situ*, but essentially as the replacement of such a decomposition product, for though the ground waters may have derived their mineral content from the underlying rock, they may also have brought it from sources widely separated. A laterite may thus result from the individual or combined decomposition of basalts, gneisses or schists, and there may, in its hardened upper surface, be no particle of the rock whose former place it now occupies." The conclusions announced by the writer are as follows:

"1. Lateritic deposits are restricted geographically, because they require for their formation—

(a) Tropical heat and rain with concomitant abundant vegetation.

(b) Alternating wet and dry seasons.

"2. Their restriction in altitude is only apparent. Their present lines of altitude merely mark ancient or existing basin floors or plains.

"3. They are derived from mineralized solutions brought to the surface by capillarity, and are essentially replacements (either mechanical or metasomatic) of soil or of rock decomposed *in situ*, or of both.

"4. In the humid regions of India the tendency of change in laterites is toward hydration and not toward dehydration.

"The foregoing replacement hypothesis would appear to supply a fairly reasonable explanation for all the eccentricities of laterite."

Abundant references are given in this article and these seem to have been examined with critical discrimination by the author.

The formation and distribution of essential oil in a living plant is the object of researches made at Paris by Messrs. Charabot and Lalove. In their recent experiments they took up the plant wormwood (*Artemisia absinthium*) for examination. Cuttings of the plant were taken at different epochs of vegetation, first on September 26, 1904, about six months after sowing and long before flowering, second on July 10, 1905, at the commencement of the flowering, third on August 4, when the flowering was already advanced, and lastly on September 2, 1906, at the end of the flowering. At this time the old leaves commenced to dry up, but a great number of others came from an abundant new growth which started near the base. During the first stage, long before the flowering, there is a preponderance of leaves. The roots do not as yet contain any essential oil. As to the leaves, they contain a much greater amount than the stalks, or eleven times as much. In the second stage, or the beginning of the flowering, the stalks, as distribution organs, have become predominant. The root, which did not yield any essential oil in the first period, now becomes richer than the stalk. In all the organs, the proportion of oil has increased, and in the leaf it has doubled. The conclusion taken from the analyses is that there is an important formation of essential oil up to the time of flowering. But this formation coincides with the growth of the plant, and it is to be remarked that the proportion of odorant matter to dry matter remains about the same as during the first period. Coming to the third stage, when the flowering is advanced, the flowers are an important part of the plant, but the stalks predominate. The accumulation of essential oil in the roots becomes more manifest, and they never observed this for an annual plant. The proportion of oil is lessened considerably in the stalks, in the leaves and especially in the flowers. In short, it diminishes in the plant, considering either fresh or dry matter. Thus it is in the beginning of the development that the odorous compounds are the most actively formed. The conclusion is that there is a consumption of odorous matter on account of the work of fecundation. From a practical standpoint they show that it is an advantage to give a judicious choice to the time of collecting odoriferous plants. In the present experiments, according as they were collected on July 10 or August 4, each plant gave 1,055 milligrammes, or only 766 milligrammes of essential oil respectively. For the latter case there is a great loss. In other words, the practical conclusion is that it is of interest to prevent the fecundation of the flower or else to extract the oil before this takes place. In the last stage, the flowering is finished and the leaves have taken a greater relative importance on account of a new growth which is produced. A great part of the plant is thus re-

newed, and the proportion of essential oil in the root has largely increased. In the dry matter of the stalk there is a slight increase, but no great change in the dry leaf. There is a lessening in the flower, but taking the whole plant the amount of oil is increased owing to the new growth.

TRADE NOTES AND FORMULÆ.

Polishing Powder for Mirrors.—Powder and mix 60 parts by weight of Cologne chalk, 30 of tripoli, and 15 of bale. Moisten the glass a little, apply the powder with a rag, and rub till the glass is clean.

Spot Remover for All Fabrics.—A spot remover which can be used without the slightest injury even to the most delicate colors is prepared as follows: Take 25 parts by weight of purified turpentine oil and 1.5 each of the finest rectified spirit and sulphuric ether; mix thoroughly with 15 drops of lemon oil and keep in a closed bottle. First moisten the spots with this preparation; then dip a suitable piece of rag in the liquid and rub the spots out with it.

To Close Seams in Tanks.—Wet clay is often used for filling up seams in tanks, etc. Clay has its greatest expansion when wet; as it dries it contracts, and will no longer close up the seams perfectly. The process may be reversed with advantage. The clay should be dried and reduced to powder, and then placed in the seams in this form. It then absorbs but little water, and will fit into the seams perfectly when expanded. The greater the pressure of the water in the reservoir, the better will the clay fit.

To Bleach Straw.—Pour boiling water over the straw, leave the straw in the water for 24 hours, and repeat the operation till the water is only slightly colored. Then treat with three hot liquids, each consisting of 100 parts of water and 24, 16, and 12 of soda, respectively. Allow the straw to remain for 24 hours in each. Then rinse with boiling water, immerse in a bath of chlorine and afterward in a bath of sulphurous acid, and wash. The straw will be rendered perfectly white by this treatment, and will remain supple and flexible.

Resistive Varnish on Copper.—To prepare a varnish which will resist the action of heat and acid fluids up to a certain point, heat finest viscid amber varnish till it is sufficiently thin to be applied with a brush; coat the article with the varnish, and allow the latter to get completely dry. Then heat the article till the varnish begins to smoke and takes on a brown color. If this process is twice repeated, a coating will be obtained superior even to enamel in its power of resisting the action of acids, but on the other hand exceedingly sensitive to slightly alkaline liquids.

To Bleach Ostrich Feathers.—I. Dissolve 4 to 5 parts by weight of potassium permanganate in 1,000 of water, adding a solution of magnesium sulphate of the same strength; do not heat beyond 60 deg. C. (140 deg. F.). Wash the feathers, previously coated with a layer of peroxide, in this mixture, and finally immerse them in diluted sulphuric acid of 1 deg. to 2 deg. Bé. II. Dissolve 10 parts by weight of barium peroxide in 1,000 of water; heat to 30 deg. C. (86 deg. F.); leave the feathers for forty-eight hours in this solution; wash; pass through a weak bath of hydrochloric acid, and dry.

To Prevent Dye on Leather from Coming off.—Make a casein solution by heating 500 parts by weight of water, adding 250 parts of ammonia as soon as the water begins to boil, thoroughly dissolving 50 parts of casein in the mixture with constant stirring, and diluting with clear water to about 6,000 parts. The solution can be applied in a thin and even coating to the still wet leather immediately after the coloring, and allowed to sink in. If the leather is already dry, a weaker solution should be used. This casein solution is also used successfully with leather already worked up by shoemakers. The leather must previously be well brushed and, if possible, washed with lukewarm water. The water is drained off, the casein applied to the leather and allowed to sink completely into it.

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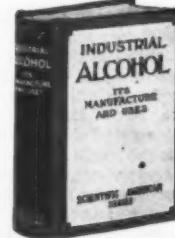
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